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Storm water runoff samples were collected from 15 "discrete" test areas in the Tulsa metropolitan area for laboratory analysis in terms of quality standards for BOD, COD, TOC, organic Kjeldahl nitrogen, soluble orthophosphate, chloride, pH, solids, total coliform, fecal coliform, and fecal streptococcus pollutants.

Selected land use parameters, environmental conditions, drainage and precipitation data, along with storm water pollution factors, provided input data for functional relationships to enable assessment of pollution from storm water runoff.

Recommendations were made for a plan of action for preventing and controlling storm water pollution from urban areas.

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Storm Water Pollution
from
Urban Land Activity

Development of Analytical Procedures
for Predicting Storm Water Pollution from Urban Areas
by Use of Selectively Defined Urban Characteristics

Federal Water Quality Administration
Department Of The Interior

by

AVCO Economic Systems Corporation
1025 Connecticut Avenue, N. W.
Washington, D. C. 20036
A Subsidiary of Avco Corporation

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ABSTRACT

An investigation of the pollution concentrations and loads from storm water runoff in an urban area was conducted in Tulsa, Oklahoma. The scope of the project included: a field assessment of the storm water pollution by obtaining samples of the water resulting from precipitation and surface runoff from selected test areas within the metropolitan area; development of an analytical procedure for correlation of storm water pollution with selectively defined variables of land uses, environmental conditions, drainage characteristics, and precipitation; and development of a plan for implementing remedial measures necessary to abate or control sources of pollution in an urban area.

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Selected land use parameters, environmental conditions, drainage and precipitation data, along with storm water pollution factors, provided input data for functional relationships to enable assessment of pollution from storm water runoff.

Recommendations were made for a plan of action for preventing and controlling storm water pollution from urban areas.

This report was submitted in fulfillment of Contract 14-12-187, between the Federal Water Quality Administration and the AVCO Economic Systems Corporation.

KEY WORDS: STORM WATER POLLUTION, URBAN RUNOFF, LAND USE INDICATORS

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SECTION 1

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Findings

1. Analytical Results - The data presented in Table 1 summarizes the assessment of pollution parameters measured on 15 urban watersheds.

TABLE 1

SUMMARY OF THE ANALYTICAL RESULTS

Parameter	Mean of the Test Areas	Range of the Test Area Means
Bacterial (number/100 ml)[a]		
Total coliform	87,000	5,000-400,000
Fecal coliform	420	10- 18,000
Fecal streptococcus	6,000	700- 30,000
Organic (mg/l)		
BOD	11.8	8- 18
COD	85.5	42-138
TOC	31.8	15- 48
Nutrients (mg/l)		
Organic Kjeldahl nitrogen	0.85	0.36-1.48
Soluble orthophosphate	1.15	0.54-3.49
Solids (mg/l)		
Total	545	199-2242
Suspended	367	84-2052
Dissolved	178	89-400
Other Parameters		
pH	7.4	6.8-8.4
Chloride (mg/l)	11.5	2- 46
Specific conductance (micromhos/cm)	108	36-220

[a] Geometric mean.

2. Functional Relationships - Regression analysis was used to determine predictor models for estimating urban pollutant concentrations. Inputs for this phase of the study consisted of the analytical results from the test areas and tabulated groups of independent variables describing both the precipitation regimen and land surface characteristics of each test area. The best regression equations determined in these analyses are shown in Tables 2 through 5.

Table 2 shows a listing of the best multiple regression equations developed using the precipitation variables and the associated sample results. These equations are suitable for estimating the pollution concentrations from characteristics which describe individual precipitation events.

The equations developed in the analysis of land surface characteristics can be used to estimate the average concentrations of pollutants in the storm runoff from urban areas. Table 3 presents the best equations developed with data from combined land uses. Table 4 contains equations derived using data from Test Areas No. 3, 5, 7, 8, 9, 13, and 15--the "residential" test sites. The equations from Test Areas No. 1, 2, 4, 6, 10, and 11--the commercial and industrial sites--are presented in Table 5.

3. Estimates of Pollution Loadings - The estimated average annual storm water pollution loads for each of the test areas were obtained by multiplying the average pollutant concentrations by the estimated annual volumes of runoff. This calculated load for each site is depicted in pounds per acre per year in Table 6 and in pounds per day per mile of street in Table 7. Both tables can aid in comparing the pollution generating capacities of each site.

TABLE 2

SELECTION OF BEST MULTIPLE REGRESSION EQUATIONS FOR PRECIPITATION VARIABLES

Regression Equation[a]	Correlation (R)	F-Value[b]	Equation Number
Total Coliform (Thousands/100 ml)			
$\ln Y_1 = 5.2598 - 0.0853 (Z_1) - 0.9638 (Z_2) - 0.8297 (Z_5)$	0.232	7.27**	K-9
Fecal Coliform (Number/100 ml)			
$\ln Y_2 = 1.5072 - 0.0039 (Z_4) - 0.6503 (Z_5) + 12.3412 (Z_7)$	0.324	13.88**	K-20
Fecal Streptococcus (Thousands/100 ml)			
$\ln Y_3 = 2.7615 - 0.3901 (Z_1) + 1.1460 (Z_2) - 0.0039 (Z_4)$	0.416	30.21**	K-28
BOD (mg/l)			
$\ln Y_4 = 2.7531 + 0.0086 (Z_1) - 0.6484 (Z_2) - 0.3674 (Z_5)$	0.274	11.21**	K-39
COD (mg/l)			
$\ln Y_5 = 4.5757 - 0.0246 (Z_1) - 0.2001 (Z_2) - 0.0900 (Z_3)$	0.215	5.78**	K-47
Total Solids (mg/l)			
$\ln Y_9 = 5.7304 - 0.0144 (Z_1) + 0.0572 (Z_2) + 0.3004 (Z_3)$	0.103	1.45	K-57

[a] Legend for dependent and independent variables

Y_i = Pollution parameter concentration
Z_1 = Time since start (hrs.)
Z_2 = Antecedent amount (in.)
Z_3 = Antecedent average intensity (in./hr.)
Z_4 = Time since antecedent event (hr.)
Z_5 = Amount of antecedent event (in.)
Z_7 = Average intensity of antecedent event (in./hr.)

[b] The 99 percent significance level is indicated by two asterisks (**)

TABLE 3

SELECTION OF BEST REGRESSION EQUATIONS FROM ANALYSIS OF LAND SURFACE CHARACTERISTICS OF COMBINED LAND USE TEST AREAS

Regression Equation[a]	F-Value[b]	Equation Number
Total Coliform (Thousands/100 ml)		
$M_1 = 430 - 363 (X_1)^c$	35.76**	K-76
Fecal Coliform (Thousands/100 ml)		
$M_2 = -11.7 + 6.92 (X_1) + 6.25 (X_{20}) - 0.396 (D_9)^d$	11.33**	K-98
Fecal Streptococcus (Thousands/100 ml)		
$M_3 = 9.30 + 6.23 (X_1) + 4.28 (X_{20}) - 5.58 (D_9)^d$	1.39	K-99
BOD (mg/l)		
$M_4 = 8.2 + 0.00065 (D_2)^d$	5.35**	K-100
COD (mg/l)		
$M_5 = 71 - 45.4 (X_1) + 2.61 (X_{21}) + 0.00619 (D_2)^d$	6.32**	K-109
Organic Kjeldahl Nitrogen (mg/l)		
$M_7 = 0.16 + 0.266 (D_6)^d$	34.87**	K-116
Soluble Orthophosphate (mg/l)		
$M_8 = 0.62 + 0.08 (X_{29})^c$	21.26**	K-89
Total Solids (mg/l)		
$M_9 = 212 + 50.2 (X_{29})^c$	15.13**	K-93
Suspended Solids (mg/l)		
$M_{12} = 187 + 24 (X_{25})^c$	15.39**	K-95

[a] Legend for dependent and independent variables:
M_i = Arithmetic mean (by events) of parameter concentration (geometric mean by events for bacterial parameters)
D_2 = Length of main stream (ft.)
D_6 = Average land slope (%)
D_9 = Form factor (dimensionless)
X_1 = Environmental Index (dimensionless)
X_{20} = Covered sewer/total length (ratio)
X_{21} = Arterial streets (%)
X_{25} = Industrial land (%)
X_{29} = Unused space (%)

[b] Levels of significance:
* 95 percent level
** 99 percent level

[c] Data taken from all 15 test areas.

[d] Data taken from all test areas except 1, 12, and 14.

TABLE 4

SELECTION OF BEST REGRESSION EQUATIONS FROM ANALYSIS OF LAND SURFACE CHARACTERISTICS OF RESIDENTIAL TEST AREAS[a]

Regression Equation[b]	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)		
$M_1 = 521 - 427\ (X_1)$	17.75**	K-131
Fecal Coliform (Thousands/100 ml)		
$M_2 = 0.884 + 0.806\ (X_1) - 0.396\ (X_{20}) + 0.543\ (D_9)$	0.26	K-145
Fecal Streptococcus (Thousands/100 ml)		
$\ln M_3 = 2.4741 - 1.216\ (X_1) - 0.115\ (X_{17}) + 2.076\ (X_{20})$	0.42	K-150
BOD (mg/l)		
$M_4 = 21.7 - 0.05\ (X_{22})$	2.89	K-156
COD (mg/l)		
$M_5 = 69 - 74.71\ (X_1) + 5.68\ (X_{21}) + 0.0105\ (D_2)$	16.55**	K-164
Organic Kjeldahl Nitrogen (mg/l)		
$M_7 = 2.01 - 1.00\ (X_{20})$	7.73*	K-169
Soluble Orthophosphate (mg/l)		
$M_8 = 0.66 - 0.0011\ (X_{21}) + 0.0645\ (X_{29})$	4.01	K-179
Total Solids (mg/l)		
$M_9 = -139 - 15.4\ (X_{20}) + 16.0\ (X_{22}) + 2.57\ (D_4)$	1.41	K-187
Suspended Solids (mg/l)		
$M_{12} = 791 - 312\ (X_1) - 288\ (X_{20}) + 1.32\ (X_{21})$	2.17	K-190

[a] Test Areas No. 3, 5, 7, 8, 9, 13, and 15.

[b] Legend for dependent and independent variables:

M_i = Arithmetic mean (by events) of parameter concentration (geometric mean by events for bacterial parameters)
D_2 = Length of main stream (ft.)
D_4 = Fall of drainage area (ft.)
D_9 = Form factor (dimensionless)
X_1 = Environmental Index (dimensionless)
X_{17} = Residential density (people/res. acre)
X_{20} = Covered sewer/total length (ratio)
X_{21} = Arterial streets (%)
X_{22} = Other streets (%)
X_{29} = Unused space (%)

[c] Levels of significance:
* 95 percent level
** 99 percent level

TABLE 5

SELECTION OF BEST REGRESSION EQUATIONS FROM ANALYSIS OF LAND SURFACE CHARACTERISTICS OF COMMERCIAL AND INDUSTRIAL TEST AREAS[a]

Regression Equation[b]	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)		
$M_1 = 372 - 329 (X_1)$	25.66**	K-193
Fecal Coliform (Thousands/100 ml)		
$M_2 = 5.64 + 5.25 (X_{20})$	10.58*	K-203
Fecal Streptococcus (Thousands/100 ml)		
$M_3 = 37.29 - 6519 (X_{14})$	19.65*	K-210
BOD (mg/l)		
$M_4 = 8.3 - 0.709 (X_1) + 1.10 (X_{19}) + 0.00028 (D_2)$	2.22	K-222
COD (mg/l)		
$M_5 = 152-52.2 (X_1) + 1.72 (X_{21}) - 21.7 (D_9)$	2.89	K-230
TOC (mg/l)		
$M_6 = 3.8 + 4.76 (X_1) + 2.10 (X_{19}) + 0.0055 (D_3)$	15.74*	K-233
Organic Kjeldahl Nitrogen (mg/l)		
$M_7 = 0.31 - 0.081 (X_1) - 0.0507 (X_{20}) + 0.265 (D_6)$	11.24*	K-241
Soluble Orthophosphate (mg/l)		
$M_8 = 1.35 + 0.0252 (X_{25}) + 0.0622 (X_{29})$	5.26	K-248
Total Solids (mg/l)		
$M_9 = 162 + 67 (X_{29})$	9.51*	K-254
Suspended Solids (mg/l)		
$M_{12} = -3 + 65.9 (X_{29})$	10.25*	K-260

[a] Test Areas No. 1, 2, 4, 6, 10, and 11.

[b] Legend for dependent and independent variables:
- M_i = Arithmetic mean (by events) of parameter concentration (geometric mean by events for bacterial parameters)
- D_2 = Length of main stream (ft.)
- D_3 = Length to center of area (ft.)
- D_6 = Average land slope (%)
- D_9 = Form factor (dimensionless)
- X_1 = Environmental Index (dimensionless)
- X_{14} = Arterial streets (mi/acre)
- X_{19} = Main covered storm sewer (miles)
- X_{20} = Covered sewer/total length (ratio)
- X_{21} = Arterial streets (%)
- X_{25} = Industrial land (%)
- X_{29} = Unused space (%)

[c] Levels of significance:
- * 95 percent level
- ** 99 percent level

TABLE 6

CALCULATED AVERAGE YEARLY LOADS

Test Area	Acres	Pollution Load: lbs. /acre/year BOD	COD	Organic Kjeldahl Nitrogen	Soluble Orthophosphate	Total Solids
1	686	30	250	2.5	8.0	5100
2	272	27	150	3.3	2.9	920
3	550	14	110	2.6	3.3	1200
4	938	44	320	3.0	3.3	1900
5	507	33	250	1.3	1.6	490
6	368	21	160	1.1	1.5	600
7	197	15	90	1.5	1.3	790
8	211	33	250	1.5	2.5	840
9	64	20	230	1.3	2.0	830
10	206	48	470	3.6	3.1	1900
11	815	35	290	1.7	2.1	1400
12	223	25	140	1.2	1.7	630
13	212	25	150	2.4	2.0	780
14	263	12	60	1.1	1.1	660
15	74	25	90	0.8	1.7	570

TABLE 7

AVERAGE DAILY LOADS PER MILE OF STREET

Test Area	Total Street Miles	Average Load: lbs. /day/mile of street				
		BOD	COD	Total Solids	Organic Kjeldahl Nitrogen	Soluble Orthophosphate
1	11.46	4.85	41.10	838	0.41	1.30
2	7.41	2.54	15.12	92	0.32	0.29
3	14.87	1.41	11.46	120	0.26	0.34
4	28.40	3.98	29.29	175	0.28	0.30
5	16.32	2.80	21.43	43	0.11	0.13
6	12.24	1.70	12.73	49	0.09	0.13
7	6.84	1.20	7.20	63	0.12	0.10
8	6.97	2.72	20.89	69	0.12	0.21
9	3.11	1.12	13.09	47	0.07	0.11
10	12.99	2.10	20.44	82	0.16	0.13
11	49.05	1.60	13.29	66	0.08	0.15
12	3.39	4.53	25.47	113	0.22	0.30
13	5.58	2.58	15.16	81	0.25	0.20
14	2.07	4.26	20.54	23	0.37	0.38
15	2.06	2.47	8.67	56	0.07	0.17

Conclusions

1. The largest portion of the pollutants from the urban test areas which were studied resulted from (1) washout of materials which were deposited on the impervious areas and (2) the erosion of drainage channels caused by the high volumes of runoff generated on the impervious portions of the test areas.

2. The season of the year with the greatest amount of runoff also produces the largest amounts of pollutants. For example, during the period of record used in the hydrological portion of the study (1964-1968), the months of March, April, and May produced only 28 percent of the annual average precipitation. In this same period, however, about half of the annual runoff occurred. Therefore, even though pollutant concentrations in urban watersheds might have been higher during events occurring in other seasons, the larger runoff coefficient during these three months, with its stimulated effects on yield, would produce the greater amount of pollutants,

3. The functional relationships developed in this study between storm water pollution parameters and variables grouped in either the precipitation regimen or the land surface characteristics classification can be used to obtain a first order estimate of the average pollutant concentrations in urban watersheds at other geographical locations. These techniques provide an applicable procedure for looking at the impact of urban storm water pollutional loads to the receiving streams and for planning storm water pollutional control strategy for water quality management.

4. Principal component analysis can be used to rank the watersheds of an urban area after pollutional loads and other base measurements have been measured on a reference drainage basin within the area. In place of sampling, information and data obtained from maps, local municipalities, and local health departments can be used to compare the pollutional generating capacity of urban watersheds.

5. The land surface characteristics which have the strongest parametric relationships with storm water pollutant concentrations are the environmental conditions, the geomorphic characteristics which affect drainage, and the degree of development. The last-mentioned characteristic is evidenced by the amount of streets, the type of streets, the amount of main covered storm sewer, and the ratio of covered storm sewer to total length.

6. Land surface characteristics which influence the drainage of a watershed affect the amounts of pollution produced per unit area to a larger degree than the recorded environmental deficiencies or the types of land activity. For example, Test Area No. 9 had a bad environment as determined by the number of total deficiencies, and ranked the highest of all sites in the number of total coliform. The drainage characteristics of the area were poor, however, and relatively small yields of pollutional material were washed from the watershed in storm runoff.

7. A good prediction variable for the bacterial pollution parameters was found to be the Environmental Index, which reflects the general sanitary conditions of the sites. This index can be calculated by the procedure explained in Section 6 of this report. An alternate approach for calculation of an environmental index is through principal component analysis as presented in Section 10.

8. The regression equations developed with the precipitation variables and all associated samples indicated the existence of several meaningful relationships. Pollutant concentrations, for example, decreased with both the time since the start of the current precipitation event and the time since the antecedent event. The bacterial and total solids concentrations increased with the average intensity of the current precipitation event.

9. The analysis of the precipitation variables and BOD values taken during the rising limb of the runoff hydrograph indicated that the BOD concentrations decreased with increasing flow. The amounts of BOD contained in the flow increased with runoff rates because the time rate of flow increased at a greater rate than the BOD concentration decreased.

10. Examination of the analytical results indicates that there is a decrease in the amount of pollution produced per unit area of commercial and industrial use if the daily number of people who visit the area is high. The frequency and degree of maintenance operations increase with the number of daily visitors entering an area, whereas maintenance functions are not performed at the same frequency or degree if the number of daily visitors is low.

11. The study results indicate that, in the residential sector, the amount of pollution produced per unit area increases with the population density and/or the number of developed parcels.

12. Considering calculations using the results of this study and data from Tulsa's sewage treatment plants, it is reasonable to conclude that, with the continued urbanization of the area in conjunction with the demands for increased efficiencies in waste treatment facilities, storm water runoff in Tulsa will eventually become the prime source of pollution in the area receiving streams.

Recommendations

The recommendations presented below are based on the findings of the study which are applicable to all urban areas with separate storm drainage systems. Remedial measures and research of the nature proposed herein would reduce storm water pollution from urban areas. Specific recommendations and controlling storm water pollution in Tulsa are presented in Appendix N.

1. Three approaches to the abatement and control of dispersed pollution loads appear to be the most promising. These are: (1) a reduction in total runoff, (2) a reduction in the rates of runoff, and (3) environmental policy. It is therefore recommended that structural measures be implemented to effect control within the first two areas. Examples of the type of control measures which might be used are:

   - devices or schemes that would eliminate or deplete runoff in the urban area.

   - the use of impoundments or catch basins to attenuate flows and thus reduce the rate of runoff.

   - implementation of upstream retention programs for open spaces within the urban complex.

   In the third area, it is recommended that environmental controls on storm water pollution be invoked through the enactment of:

   - regulations and enforcement procedures to control urban litter and general sanitary conditions of public and private areas.

   - performance standards in subdivision regulations for builders and contractors during periods of land development. These standards would deal with such measures as would (1) minimize periods of exposing bare soil, (2) enhance housekeeping activities during and after construction, and (3) strengthen specifications for drainage practices followed during construction periods.

- open storage and drainage regulations for commercial and industrial areas.
- improved street cleaning and drainage channel maintenance practices with the primary intent of storm water pollution control rather than aesthetics or flood control.

2. In investigations such as this which rely on precipitation as the prime mover or cause of events that are to be studied, the time span of the project should be adjusted to compensate for the irregularity in the occurrence of study events.
3. The influential role exerted by the physical characteristics of watersheds on the future runoff regimen in a developing urban area must be recognized by the municipal agencies charged with planning and public works.
4. It is recommended that an investigation should be initiated to determine the correlation between the results of this study and measurements of pollution parameters in storm runoff from areas both in the "natural" state and those with a developed agriculture. Knowledge of the pollutants derived from these types of land uses is necessary for the complete assessment of storm water pollution within the metropolitan fringe areas and at the rural interface.

SECTION 2

INTRODUCTION

This has been an investigation of urban area storm water pollution, or more precisely, an assessment of pollution in storm water as it relates to land activity. The central purpose of this effort was to design a method of analysis which would enable the city planner and engineer to assess the quality as well as quantity of storm water, and to do so by looking at land activity, selected environmental factors, and precipitation.

Although major concern in recent years regarding pollution from storm water runoff has been with problems of combined sewage systems, storm water pollution is also a real and urgent problem in areas having separate storm and sanitary systems. Considerable quantitative data regarding the pollution from combined and separate sewers are available (1-4); there have also been several recent studies (5-8) into methods of control. Most of the proposed measures incorporate some type of structural system or physical treatment, such as retention, treatment, and coordinated discharge.

The control techniques discussed in this report are mainly the application of planning and management directed toward the control of pollution from land use practices rather than extensive structural facilities to treat or dispose of contaminant storm water effluents. Planning and management control techniques will be beneficial, notwithstanding the need for physical treatment to reduce the pollution load by making possible more economical treatment and/or better water quality. In other words, water quality management and physical pollution control measures are not necessarily mutually exclusive, but additive.

This report deals with an assessment of the sources of pollution from various land activities to provide possible means for control of storm water pollution by improved urban planning and land use regulation. Given the relationship of man's activities to storm water drainage, civic actions can be undertaken to reduce pollutional loads. If urban planning and proper regulation of land activity can reduce the overall costs associated with the achievement of an acceptable quality of the environment in the urban area, such activities should be considered the first order of business and an adjunct to any construction of physical systems for collection, disposal, or treatment.

In an engineering sense, the process was to relate land use, land condition, and hydrological input to a pollutional output for homogenous areas. The predicted area load thus is aggregated to provide an estimate of pollution. The process is similar to the determination of runoff from urban areas.

SECTION 3

DESCRIPTION OF THE URBAN AREA

Tulsa, Oklahoma is a relatively young city, incorporated in 1907, the same year that Oklahoma became the nation's forty-sixth state. Tulsa's population that year was approximately 12,000. The city grew very rapidly until 1930. In the following 10 years, growth was retarded by the depression, and Tulsa recorded only a 0.6% change in population. From 1940 until today Tulsa has grown rapidly to a population of over 400,000 people.

Cattle raising constituted the predominant industry of the area until the major oil discoveries at Red Fork in 1901, 1902, and 1904 and at Glenpool in 1905. Since that time, Tulsa has become known as one of the nation's leading centers for oil technology and the principal trade and distribution center for northeastern Oklahoma.

An aerial view of the central business district as it looks today is shown in Figure 1. Included in the view is the Arkansas River as it approaches the city from the west and turns to the southeast.

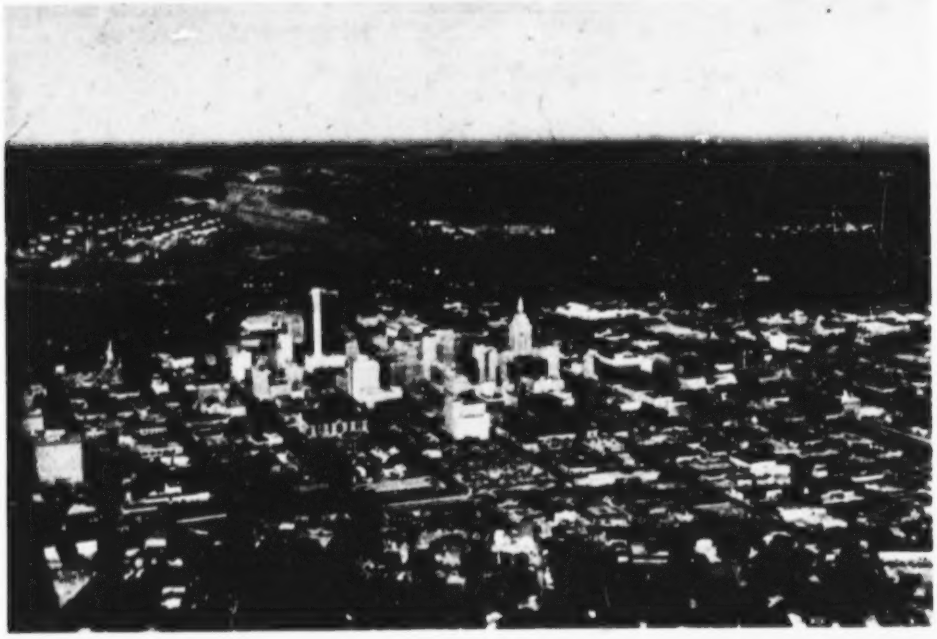


FIGURE 1. Aerial view of central business district, Tulsa, Oklahoma

Population

The population of Tulsa County in 1969 was 424,000. This compares with 346,000 in 1960 and 252,000 in 1950. An increase of about 172,000 people, or 68 percent, occurred in this 19-year period. The rate of growth for the 9-year period from 1960 to 1968 was approximately 22 percent. Various population estimates for Tulsa County, City of Tulsa, SMSA, and Tulsa Urban are presented in Table 8:

TABLE 8

VARIOUS POPULATION ESTIMATES[a]

Planning Unit	Area in Square Miles	Population
SMSA	3819	500,700
Tulsa Urban	n. a.	401,400
Tulsa County	572	424,000
City of Tulsa	172	335,000

[a] Source: Tulsa Metropolitan Area Population Estimates 1969, Tulsa Metropolitan Area Planning Commission, June, 1969.

Topographic Characteristics

The highest elevation in the Tulsa region is 1,017 feet above sea level and the lowest is 550 feet above sea level. The latter lies in the flood plains of the Arkansas River. The eastern portion of the county has hill elevations of 800 and 850 feet above sea level with valley bottoms at 600 and 650 foot elevations. In general, a north-south line formed by the Osage-Tulsa County line and extending south along the Arkansas River separates the western area of more rugged topography from the more gently undulating land to the east.

Geology

Tulsa County, located in the northeastern part of the State of Oklahoma, contains an area of approximately 572 square miles. The county is situated between the High Plains to the west and the Ozarks uplift to the east. Specifically, Tulsa County is comprised of Prairie Plains and the Sandstone Hills. The rocks are principally sandstone and shale of the Pensylvanian age. Some limestone occurs in the northern part of the county. Surface geological features of the Tulsa area result from two factors, (1) structural subsurface layers of a northeast-southwest orientation and (2) the erosion of the original surface of the earth by wind and water, followed by the uplifting and tilting of the surface, followed again by erosion forces. Hence, the surface of Tulsa County is generally rough with east-facing ranges of sandstone hills separated by flats or valleys underlaid by shale. Because of the differences in hardness of rock and because of the tilting of these rocky areas to the extent of 30 to 50 feet per mile, cuestas have been formed by erosion processes. These cuestas present their high slopes to the east and gentle slopes to the west. Escarpments are modified locally by greater erosion along streams that lead into or across them. Hence, many escarpments may be severed by the streams.

Climate

Tulsa is located in a zone with a continental type of climate. Sudden wide changes in temperature characteristic of this climatic pattern occur with the rapid passage of frontal air masses through the area. The record mean monthly temperatures range from 37.4° F in January to 82.5° F in July. This area has an average growing season of 221 days and is frost-free normally from March 25 to November 1.

The annual record mean precipitation of 37.25 inches is well distributed throughout the year. The season of maximum rainfall is spring, when much precipitation occurs through thunderstorm activity. The high levels of soil moisture and the high precipitation intensities produced by the thunderstorms help to increase the percentage of runoff during this season.

The percent of possible sunshine varies from 49 percent in January to 72 percent in July. The average annual values show Tulsa with 125 clear days, 110 partly cloudy days, and 130 cloudy days.

General Drainage Characteristics

Drainage of Tulsa County is into the Arkansas River, which crosses the county generally from the northwest to the southeast. The northern part of the City of Tulsa and the north portion of Tulsa County drain into the Verdigris River, which in turn drains into the Arkansas River at Muskogee, Oklahoma. Immediately west of the City of Tulsa, the valley of the Arkansas River is deeply incised with a flood plain less than two miles wide. Major drainage basins and their natural features are shown in Figure 2 . Figures 3 and 4 give respectively the water resources and general soil types of the Tulsa area. Table 9 contains the legend for the soils map, as well as selected land use ratings.

There are eight principal drainage basins in urban Tulsa, emptying into the Arkansas and Verdigris Rivers as follows:

Arkansas River	Verdigris River
Central	Flatrock
Berryhill	Coal
Black Boy	Mingo
Joe	
Cherry	

Central Basin can be divided into a number of sub-basins. Nearly all of Central Basin is fully developed, and portions are in the original townsite. Located along the Arkansas River are numerous drainage outfall sites ranging in size from 8" pipe to 24' x 12' arches.

The population and land use activities for six of the principal drainage basins are shown in Table 10.

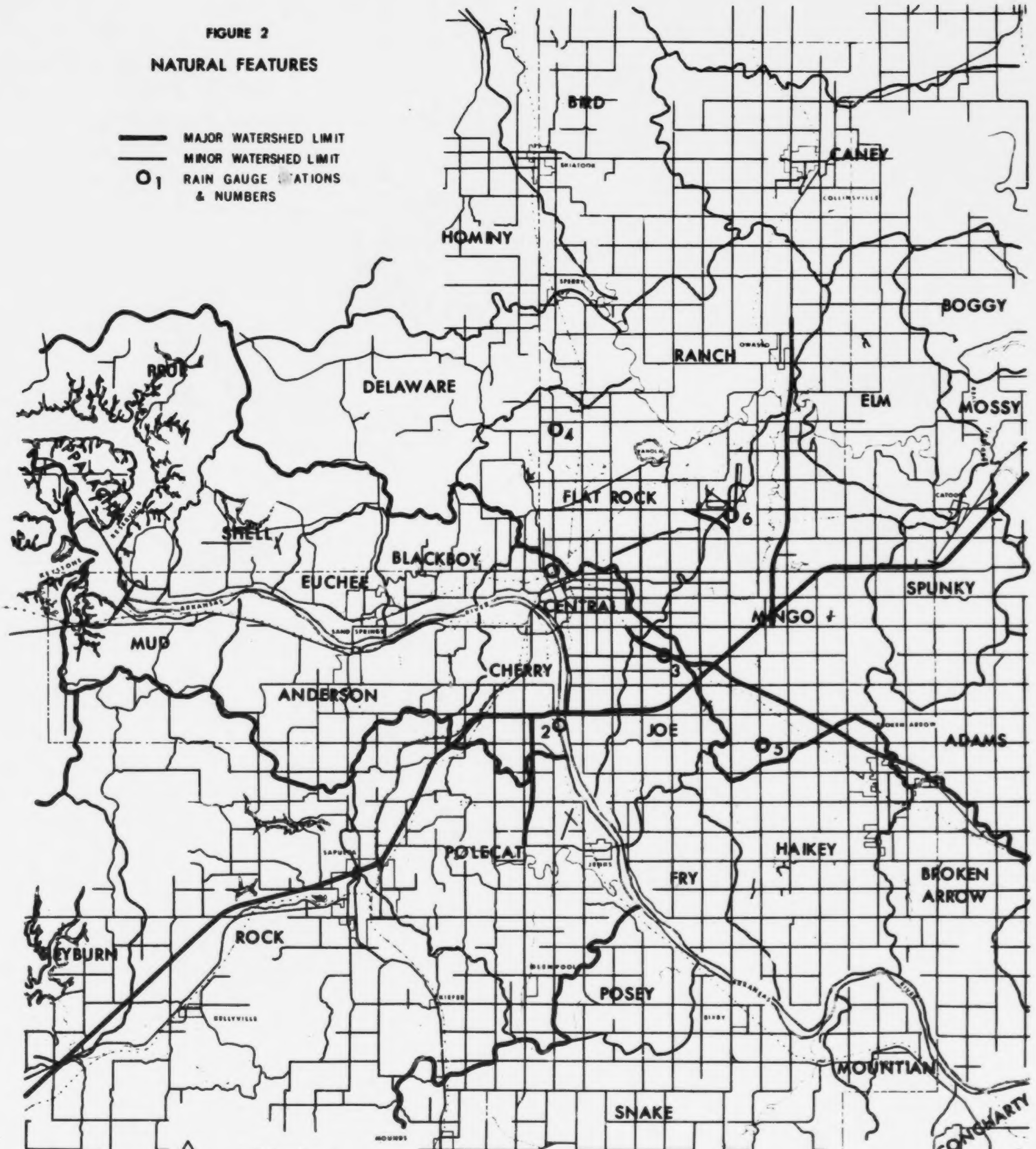


FIGURE 2

NATURAL FEATURES

MAJOR WATERSHED LIMIT
MINOR WATERSHED LIMIT
RAIN GAUGE STATIONS & NUMBERS
BIRD
CANEY
SKIATOOK
COLLINSVILLE
HOMINY
SPERRY
BOGGY
RANCH
OWASSO
DELAWARE
ELM
MOSSY
FLAT ROCK
CATOOSA
SHELL
BLACKBOY
EUCHEE
KEYSTONE
ARKANSAS RIVER
SAND SPRINGS
CENTRAL
SPUNKY
MINGO
MUD
CHERRY
ANDERSON
JOE
BROKEN ARROW
ADAMS
HAIKEY
POLECAT
SAPULPA
JENKS
FRY
BROKEN ARROW
HEYBURN
ROCK
GLENPOOL
POSEY
KIEFER
BIXBY
KELLYVILLE
MOUNTIAN
SNAKE
MOUNDS
CONCHARTY
1
2
3
4
5
6
N
FEBRUARY, 1967
Scale in Miles
tulsa metropolitan area planning commission

FIGURE 3

WATER RESOURCES

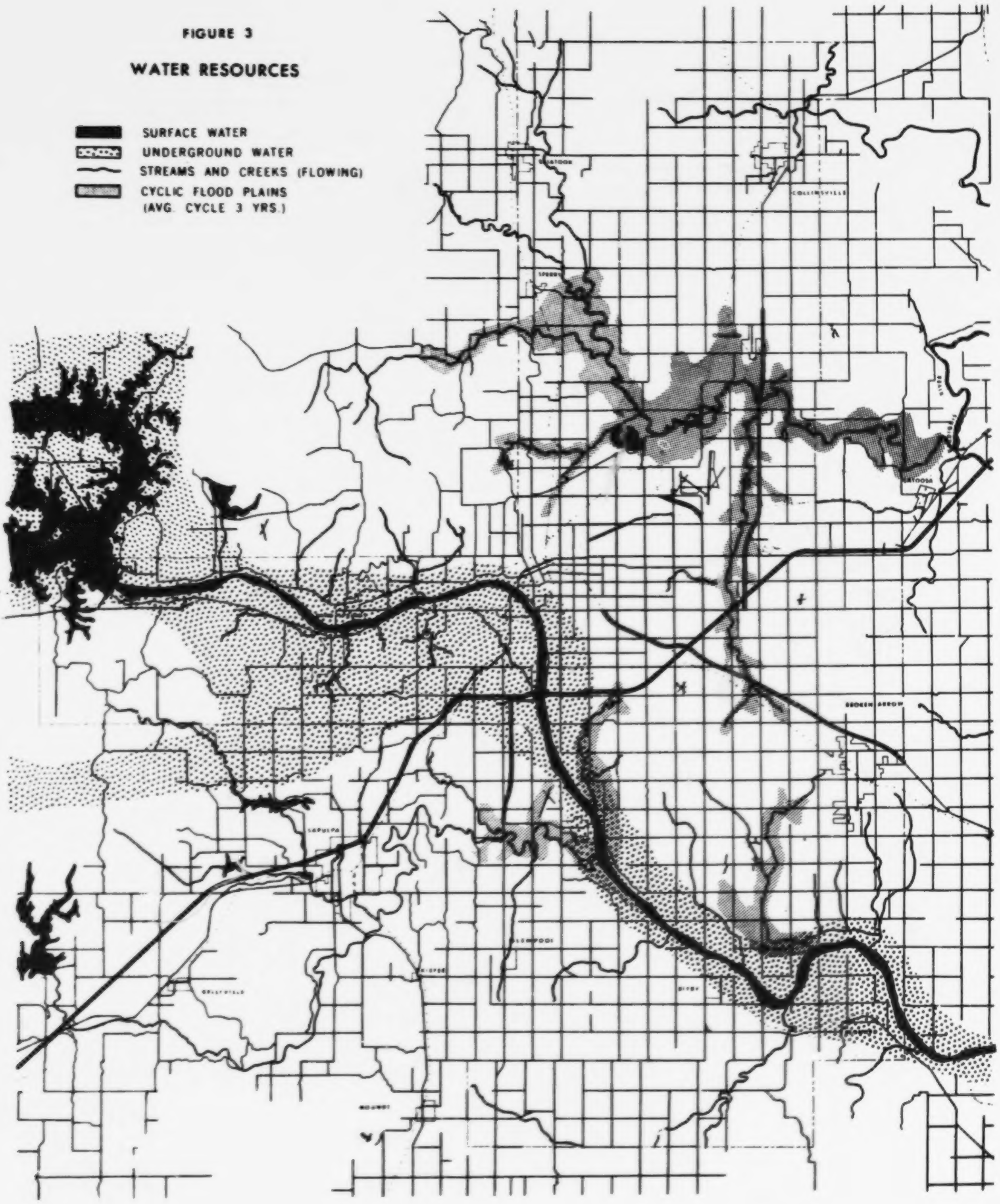
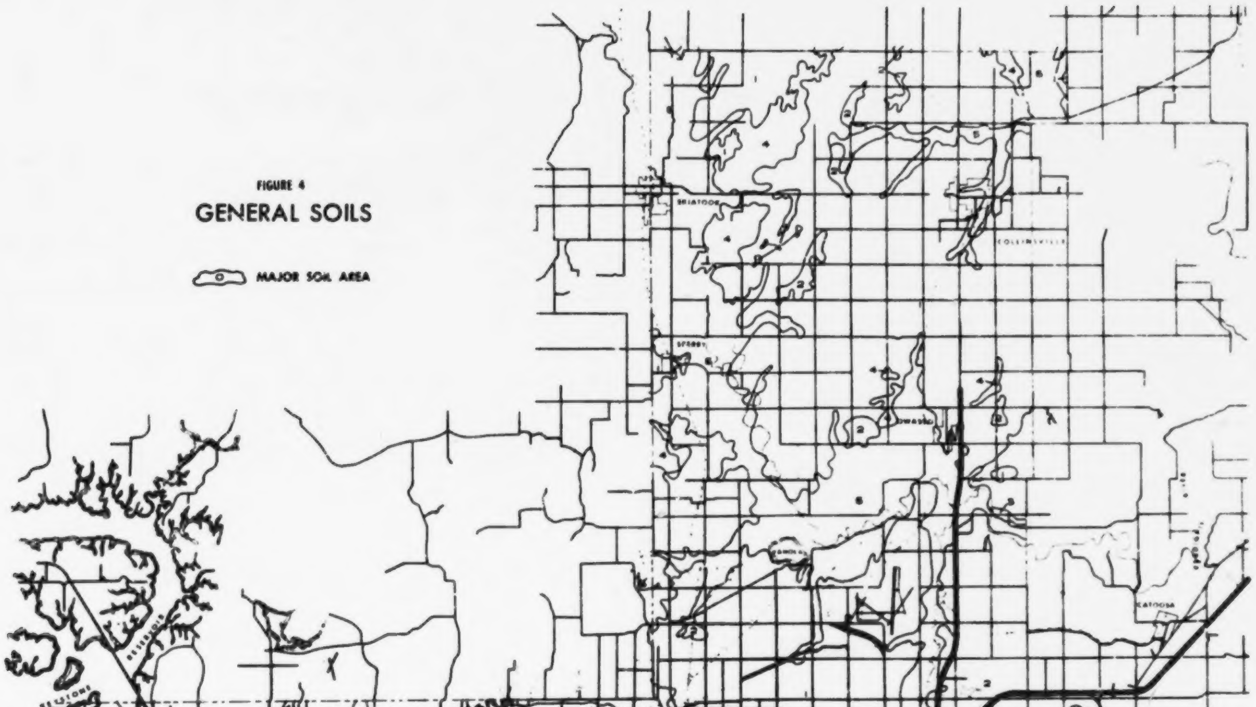

SURFACE WATER
UNDERGROUND WATER
STREAMS AND CREEKS (FLOWING)
CYCLIC FLOOD PLAINS (AVG. CYCLE 3 YRS.)
SKIATOOK
COLLINSVILLE
SPERRY
OWASSO
CATOOSA
BROKEN ARROW
SAPULPA
GLENPOOL
KIEFER
KELLYVILLE
BIXBY
MOUNDS

FIGURE 4

GENERAL SOILS


MAJOR SOIL AREA
SKIATOOK
COLLINSVILLE
SPERRY
OWASSO
CATOOSA
KEYSTONE
RESERVOIR
ARKANSAS
RIVER
SAND SPRINGS
SAPULPA
KELLYVILLE
KIEFER
GLENPOOL
JENKS
BIXBY
LEONARD
MOUNDS
N
OCTOBER, 1965
0 ½ 1 2 3
Scale in Miles

tulsa metropolitan area planning commission

TABLE 9

SUITABILITY OF SOIL ASSOCIATIONS FOR ALTERNATIVE USES[a]

Mapping Units		Use Ratings					
		Residences With		Recreation and Parks	Com. and Ind.	Agriculture	
Symbol of Map	Name	Commun. Service	Indiv. Service			Crop-Land	Pasture
1	Deep, gently sloping loamy soils on prairie uplands.	Good	Fair	Good	Good	Good	Exc.
2	Deep, nearly level loamy soils with clayey subsoils on prairie uplands.	Fair	Poor	Fair	Fair	Good	Good
3	Deep, gently sloping to strongly sloping sandy soils with loamy subsoils on wooded uplands.	Good	Good	Exc.	Poor	Poor	Good
4	Shallow to deep, gently to strongly sloping, loamy and clayey soils over sandstone and shale on prairie uplands.	Fair	Good	Good	Poor	Poor	Fair
5	Shallow to deep, gently to strongly sloping, loamy and clayey soils over limestone and shale on prairie uplands.	Fair	Poor	Fair	Fair	Poor	Fair
6	Deep, nearly level loamy and clayey soils on high bottomlands that flood rarely.	Fair	Fair	Fair	Fair	Exc.	Exc.
7	Deep, nearly level, loamy and clayey soils on low bottomlands that flood occasionally.	Poor	Poor	Good	Poor	Good	Exc.
8	Shallow to deep, gently to strongly sloping loamy and clayey soils over sandstone and shale on wooded uplands.	Fair	Good	Good	Poor	Poor	Fair
9	Arkansas River and riverwash.	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor

[a] Source: Industrial Development Plan 1990, Tulsa Metropolitan Area Planning Commission, January, 1969, p. 66.

TABLE 10

POPULATION AND LAND USE BY WATERSHED[a]

Watershed	Population	Land Use Activity Residential Acres	 Industrial Acres	 Commercial Acres	 Institutional[b] Acres
Central	95,800	5,000	380	290	1,100
Mingo	84,500	9,400	5,700	370	1,330
Flatrock	72,700	10,900	440	210	1,000
Joe	50,000	4,300	220	150	900
Coal	38,800	3,000	1,040	670	1,050
Cherry	23,500	2,800	850	800	600

[a] Source of the above information was Water and Sewage Plan 1990, Tulsa Metropolitan Area Planning Commission, March, 1969.

[b] Institutional means land that is occupied by educational or governmental establishments, churches, or cemeteries.

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SECTION 4

DESCRIPTION OF TEST AREAS

This section discusses the test areas. Fifteen test areas were selected; in each, sampling sites were identified as indicated in Figure 5. Table 11 shows the address of each sampling site, the type of drainage channel, and the type of drainage structure at each site. A general description and summary of features of the test areas are contained in Tables 12 and 13.

Methodology of Test Area Selection

Since one of the main objectives of this research was to relate pollution to land activity, it was necessary to select drainage areas with a single predominant land activity. This was accomplished in several of the areas chosen, but not in all areas. Selection of discrete (homogeneous land activity) areas was limited by a number of additional considerations. The most important of these factors were:

1. Size of area large enough to produce a measurable sample of a certain type land use.
2. Lack of known point sources of pollution in the drainage area.
3. Security of the sampling instruments from vandalism.
4. Accessibility of the sampling site.

The sites selected were determined to meet the above criteria and to provide a typical cross section of the different types of land activity.

Below are the steps followed in the delineation and selection of the test areas:

1. The storm drains were transcribed from the City Engineer's Storm Drain Atlas onto a 1" = 600' Land Use Base Map of the TMAPC.

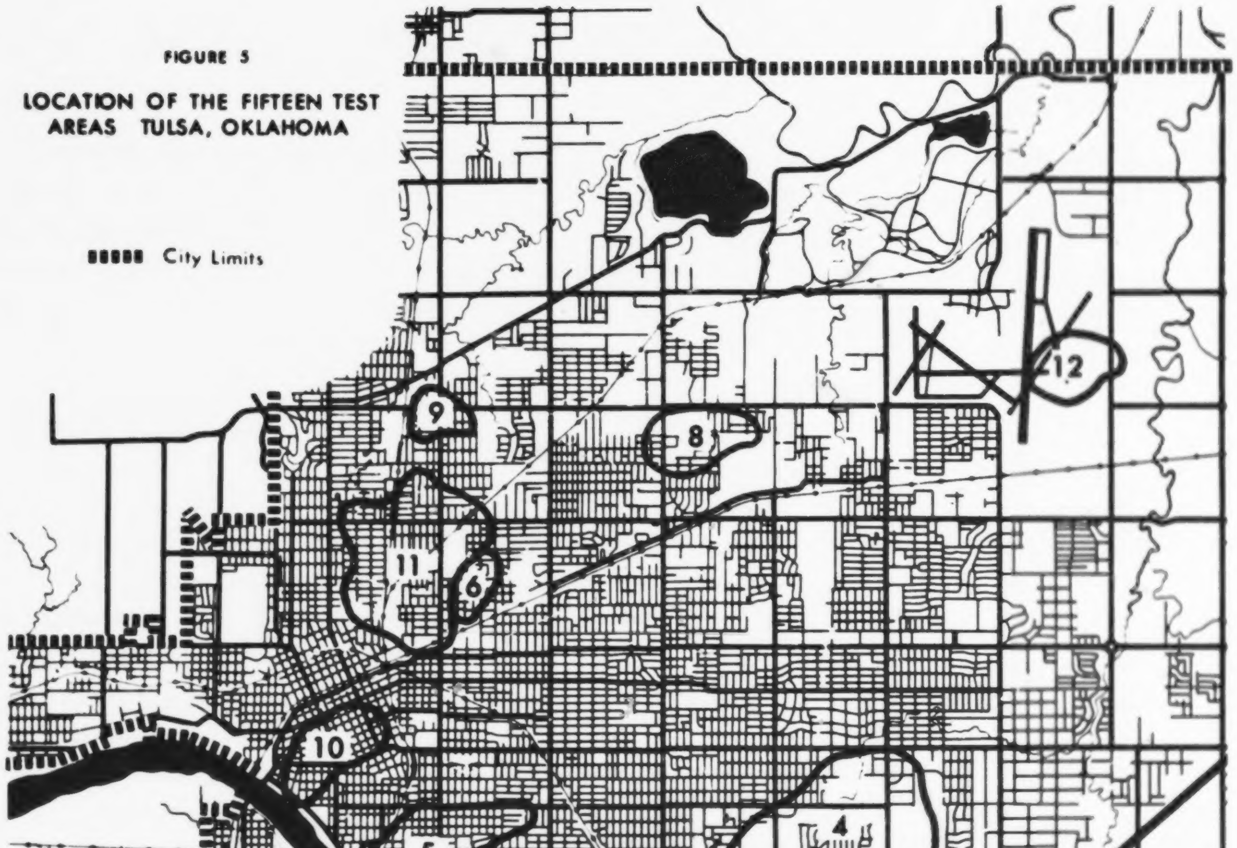

FIGURE 5

LOCATION OF THE FIFTEEN TEST AREAS TULSA, OKLAHOMA

▮▮▮▮▮ City Limits
12
9
8
11
6
10
5
4
7
13
2
15
1
3
14

2. The land use and zoning within each candidate test area were checked by use of the TMAPC's zoning maps.

3. Each test area was reconnoitered for actual conditions not shown on the maps.

4. Each test area was observed during periods of storm water runoff to better define the boundaries of the watershed.

During the early phases of the project, several of the initially selected test areas had to be dropped and new ones added. The main reason for these changes was vandalism of the sampling instruments.

The selected test areas with their drainage boundaries and major drainage conduits are illustrated in Appendix A.

Characteristics of Test Areas

Each of the fifteen test areas is described and pertinent characteristics discussed in this section.

Southern Memorial Industrial District (Test Area No. 1) - This test area is located approximately 7.5 miles southeast of downtown Tulsa. The size of the drainage area is approximately 686 acres. It is primarily a relatively new industrial district.

At present, and during the course of this investigation, this area was under development. It is predominantly zoned U-4A (Light Industrial District) and, therefore, includes warehousing, industrial sales, and light manufacturing. Some tracts with residential area are located in the lower reaches of the drainage shed.

The industrial buildings are somewhat uniform in nature and have small amounts of space for outside storage. The area is uncluttered and well-kept except for one concrete batch plant located on the bank of an unimproved open channel at the lower end of the catchment.

Southroads-Southland Shopping Center Area (Test Area No. 2) - This 273 acre test area is situated 6 miles southeast of downtown Tulsa. Located on it is the largest shopping center in urban Tulsa. Accompanying the shopping center are large paved parking areas. The shopping center is similar to those found in most cities and is composed of retail shops and general merchandise stores. It is well-kept and the parking lots are cleaned daily.

The arterial streets adjacent to the shopping center are heavily traveled. Drainage is from east to west with the shopping center located on the south and a residential area on the north. The only noticeable sources of pollution are: oil, grease, and dirt from automobiles in the parking areas; litter in the parking area and streets; and vegetation and pet manures in the residential section.

Sungate and Woodland View Area (Test Area No. 3) - This test area can be classified as an upper middle class residential neighborhood. The development is about 5 or 6 years old, and has few vacant lots. The houses of brick masonery range from 1800 to 3000 sq. ft. in floor area.

Runoff from streets passes through the inlet structures into concrete storm sewers that subsequently empty into an open channel which drains the area. This channel is grass-covered and well-kept. Some scattered shade trees are present in the watershed.

Sheridan Industrial District (Test Area No. 4) - This test area encompasses industrial, commercial, and residential uses. Industrial usage ranges from light to moderate types and includes a concrete batch plant; a cement block plant; repair shops and pipe storage facilities for the Oklahoma Natural Gas Company; oil field supply firms with accompanying outside storage; and a trucking company. A large Sears Roebuck shopping center, part of the Tulsa State Fairgrounds, grocery stores, gas stations, and drive-in restaurants comprise the commercial uses. The residential areas consist of single family housing. Structures are from 15 to 20 years old and most are well-kept. The main streets through the area are heavily traveled.

Woodward Park Area (Test Area No. 5) - The centroid of this residential test area is located approximately 20 miles south of downtown Tulsa. It is in the old section of Tulsa. This watershed is fully developed and most of the homes are large. Good grass cover exists on all yards, and the area is thickly covered with large trees.

The drainage of this watershed is from the northeast to the southwest and empties directly into the Arkansas River. The storm drainage line passes through a park near the center of the watershed. All of the drainage basin is sewered by covered channel. The outlet structure is a 7 ft. x 10 ft. arch located on the Arkansas River. At the upper part of the watershed, the size of pipe is 24 in. This increases to 102 in. before it empties into the 7 ft. x 10 ft. arch about a quarter of a mile from the river.

Latimer Industrial District (Test Area No. 6) - This test area is located 2.0 miles north of downtown Tulsa. It is a mixture of industrial and residential activity. Industrial operations include a Dowell Chemical Company facility, a trucking company, a steel fabrication company, and several auto salvage yards. Associated with the industrial operations are large areas of open storage. The houses in the residential portion are old and not well-kept. The area is drained by a covered channel which starts in the upper reaches as a 36 in. concrete pipe and ends as a 4 ft. x 8 ft. box culvert.

Methodist Manor (Test Area No. 7) - This test area is entirely residential. The homes are ten to fifteen years old and they average 1200 to 1600 sq. ft. in floor area. The entire watershed is drained by an enclosed conduit which has a semielliptical main line.

The sampling site for this drainage shed is located where the semielliptical pipe opens into an unimproved natural channel. At this location, water stands and is backed up for a distance in the pipe. This situation causes suspended particles and trash to settle out in the mouth of the drainage structure, thereby altering the hydraulic capacity of the channel. During periods of no runoff, the sludge in the bottom of the pipe can become septic, adding to the pollutional load when runoff occurs.

Strip-Pit Collection Basin (Test Area No. 8) - The storm drainage from this test area dumps into an abandoned strip-pit and normally does not reach a receiving stream as surface flow. The strip-pit has an overflow (30 in. round concrete pipe) but, except during an excessively heavy runoff event, no overflow from the pit occurs.

Land use in the drainage basin is primarily residential. Most of the streets in the residential area are not guttered. Some industrial activities are located, however, in the upper portions of the basin.

At the sampling site for this area, the same condition exists as for Test Area No. 7. The flow is restricted and back-up occurs for a distance in the pipe.

Sunny Slope Addition (Test Area No. 9) - This test area is located north of downtown Tulsa and is in the Model Cities Area of Tulsa. It is in a portion of the city that can be classified as the lower socio-economic class. The environmental conditions in this watershed are bad. There are large and numerous accumulations of rubbish. The yards are poorly kept. Structures are dilapidated and near the "Urban Renewal" stage.

The watershed is small (approximately 64 acres) and well defined. It is drained by a 48 in. concrete pipe.

Southern Central Business District (Test Area No. 10) - This test area is composed of a mixture of commercial and residential land activities. The upper portion of the drainage basin consists of office-retail multiple store buildings. Included in the area are several parking lots. In the central part of the watershed is an expressway clearance project. Numerous buildings and houses have been torn down or have been in some stage of demolition during the project. The approximate area encompassed by this clearance work is 20 acres. Along the lower reaches and below the expressway project is located an old residential area.

Greenwood Drainage Shed (Test Area No. 11) - This is the second largest drainage basin investigated in the study. Most of the area is in residential use but there are some commercial land activities. Extensive holdings are devoted to railroads in the upper portion of the area.

The watershed is directly north of the downtown area and is in the heart of Tulsa's Model Cities area. At least one third of the housing can be considered in a poor or dilapidated condition. Located in the test area are urban renewal projects where buildings are being demolished and the land cleared.

Airport East (Test Area No. 12) - This test area is composed mostly of open land or runways. The only land activity of major interest is in a portion of the southwest corner containing support buildings and pads for aircraft maintenance and repair activities. This relatively small amount of activity could conceivably produce a significant amount of "exotic" pollution in the natural drainage stream.

Bolewood Acres (Test Area No. 13) - This test area is residential and is composed primarily of large tracts on which big, expensive homes have been built. Each home averages 4 to 5 bedrooms and

3 bathrooms. Almost every home in the lower portion of the watershed has a private swimming pool. Approximately 50 homes in the lower half of the watershed are not connected to a sanitary sewer and have individual septic systems. The homes in the upper portion of the test area are connected to a sanitary sewer.

The drainage channel which runs down through the middle of the watershed is a 54 in. conduit. This opens into an unimproved natural channel in the lower quarter of the basin. As the drainage leaves the watershed, the flow is divided, and one half enters a 66 in. semielliptical conduit. The sampling site for the watershed was at the mouth of the 66 in. semielliptical conduit. This is approximately two blocks south of the divided flow.

Southern Hills Country Club (Test Area No. 14) - The Southern Hills Country Club is located approximately 5. 5 miles south of downtown Tulsa. The test watershed encompasses portions of the club's golf course and some residential tracts that line the perimeter of the golf course. These residential tracts with their large, expensive houses are in the upper reaches of the catchment area.

The watershed drains to the northwest. Upon joining flow from adjacent areas, the drainage flows to the Arkansas River, which is about 1. 5 miles west of the site.

Several ponds which serve as embellishments to the golf course have been constructed on the drainage channel through the area. Only during storm events producing considerable runoff do these ponds overflow. These small ponds act as "treatment" lagoons and provide some degree of disposal for storm water runoff generated on the site.

Alt Ade Ma Place (Test Area No. 15) - Alt Ade Ma Place is the second smallest drainage area investigated on this project. This test site is one of the postwar residential areas in Tulsa and consists of small frame and brick houses. The normal tract size is approximately 0. 2 acres and the average density is 4. 96 people per acre. The area is located on the flat alluvial plain of the Arkansas River. The outfall line for storm drainage consists of a 48 in. round concrete conduit.

TABLE 11

TEST DRAINAGE BASINS AND SAMPLING SITES

Site No.	Name of Test Basin	Address of Sampling Site	Approach to Sampling Site	Structure at Sampling Site
1	S. Memorial Ind. Dist.	9000 E. 40th Place	Open Channel (Unimproved)	10 x 6 Double Box
2	Southroads-Southland	3900 S. Toledo	10 x 8 Semielliptical	Manhole into Semielliptical
3	Sungate & Woodland View	5500 S. Sheridan	Open Channel (Concrete)	8 x 4 Double Box
4	Sheridan Industrial Dist.	6100 E. 11th Street	Open Channel (Unimproved)	10 x 10 Double Box
5	Woodland Park	2600 S. Riverside	102" Concrete Pipe	7 x 10 Arch
6	Latimer Ind. Dist.	1800 N. Victor	8 x 4 Box	8 x 4 Box
7	Methodist Manor	4100 E. 31st Street	5 x 6 Semielliptical	Mouth of Semielliptical
8	Strip Pit	2100 N. Quebec	4 x 6 Semielliptical	Mouth of Semielliptical
9	Sunny Slope	900 E. 27th North	48" Concrete Pipe	Mouth of Pipe
10	Central Business Dist.	1400 S. Riverside	66" Concrete Pipe	10 x 10 Box
11	Greenwood	500 Woodrow Street	12 x 10 Semielliptical	Mouth of Semielliptical
12	Airport East	3100 N. Mingo	Open Channel (Unimproved)	10 x 6 Box
13	Bolewood Acres	4600 S. Wheeling	5 x 6 Semielliptical	Mouth of Semielliptical
14	Country Club	6100 S. Lewis	Open Channel (Unimproved)	4 x 4 Box
15	Alt Ade Ma Place	4300 S. Riverside	48" Corrugated Pipe	48" Concrete Outfall

TABLE 12

GENERAL DESCRIPTION OF THE TEST AREAS

Test Area No.	General Land Use Classification	Specific Zoning Classification	Socioeconomic Class	Remarks
1	Industrial	Pred. U-4A Small amount U-3A		Light industrial, warehousing, industrial sales--new industrial development containing little outside storage--large portion still in construction stage--water quality should reflect cement company waste in lower reaches of watershed.
2	Commercial	Pred. U-3E Some U-1C, U-2B, U-3A	Some upper middle class residential	Shopping center with large paved parking areas--includes drainage from large grassy slope (portion of Pan American Research Laboratories property).
3	Residential	Pred. U-1C Small amount U-1B, U-3DH	Upper middle class	Relatively new additions with little tree cover and well-kept lawns--area swimming pool probably drains into storm sewer--some commercial activity on major streets.

TABLE 12-- Continued

Test Area No.	General Land Use Classification	Specific Zoning Classification	Socioeconomic Class	Remarks
4	Industrial and Residential	U-4B U-1C	Residential portion: lower middle class	Light to moderate industrial with approximately 1/3 residential--far upper reaches drain portion of Tulsa State Fairgrounds--industrial area is approximately 1/2 old development and 1/2 new development or open land zoned for industrial use--considerable amount of outside storage of industrial products--railway service to most of area for shipping.
5	Residential	Pred. U-1C	Upper middle class--some lower upper class--some lower middle class in upper reaches	Large old homes--great amount of tree cover--some small old housing in upper reaches of watershed--includes some commercial activity on major streets, drainage from Woodward Park, Tulsa Garden Center, and overflow from Swan Lake.
6	Industrial	U-4B		Old industrial area with considerable amount of outside storage--water quality should reflect waste from trucking firm--lower middle class residences make up the upper and eastern reaches of the watershed.

TABLE 12-- Continued

Test Area No.	General Land Use Classification	Specific Zoning Classification	Socioeconomic Class	Remarks
7	Residential	U-1C	Upper middle class	Postwar addition of mostly three bedroom frame and brick houses with medium-sized trees--well-kept area.
8	Residential	U-1C	Lower middle class	Postwar addition of mostly two bedroom frame and brick houses with medium-sized tree cover.
9	Residential	Pred. U-1C Traces of U-4B	Lower class	Old houses of various sizes, many nearing delapidation--ill-kept area residentially with some commercial activity on major thoroughfares.
10	Commercial-Office and Residential	3/4 U-3DH and remainder in U-2A and U-2B	Some lower middle class	Upper portion of watershed is commercial-office including multi-story buildings--middle areas of watershed are largely open areas with considerable tree cover--these areas have been cleared by the Tulsa urban renewal authority for eventual redevelopment--some urban renewal work is still underway in the area--lower areas of the watershed are old residential neighborhoods containing various size houses with great amount of tree cover.

TABLE 12--Continued

Test Area No.	General Land Use Classification	Specific Zoning Classification	Socioeconomic Class	Remarks
11	Residential and Commercial	U-1C	Lower middle class	This drainage basin is in the heart of Tulsa's model city area--mostly small old frame houses with great amount of tree cover--some commercial activity on major streets.
12	Industrial and Commercial	U-4A		Runways and supporting buildings with some light industry--considerable open grassy area.
13	Residential	U-1A	Lower upper class	Non-sewered, newly laid concrete pipe into unimproved open channel--large lots with a number of swimming pools--well-kept lawns.
14	Recreational			Southern Hills Country Club--most of drainage basin includes golf course.
15	Residential	U-1C	Lower middle class	Postwar addition of small 2-3 bedroom frame and brick houses with substantial coverage of medium sized trees.

TABLE 13

FEATURES OF THE TEST AREAS

Test Area No.	Physiography	Geology	Land Slope	Type Vegetation Cover	Major Drainage Basin
1	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Mingo
2	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Joe
3	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Joe
4	Prairie Plains	Shale Group	0-5% and Small Amount of 6-10%	Prairie Grassland	Mingo
5	Flood and Prairie Plains	Shale Group & Alluvial Basins and Terraces	0-5% and Small Amount of 6-10%	Small Amount of Alluvial Forest	Central
6	Prairie Plains	Shale Group	0-5% and Small Amount of 6-10%	Prairie Grassland	Flatrock
7	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Joe
8	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Flatrock
9	Prairie Plains	Shale Group	0-5%	Prairie Grassland & Alluvial Forest	Flatrock
10	Flood Plains	Alluvial Basins & Terraces	0-5% and Small Amount of 6-10%	Alluvial Forest & Upland Woods	Central
11	Prairie Plains	Shale Group	0-5% and Small Amount of 6-20%	Prairie Grassland	Flatrock
12	Prairie Plains	Shale Group	0-5%	Prairie Grassland	Mingo
13	Flood and Prairie Plains	Alluvial Basins & Terraces	0-5% and Small Amount of 6-20%	Alluvial Forests & Prairie Grassland	Central
14	Prairie Plains	Shale Group	0-5% and Small Amount of 6-20%	Alluvial Forests & Upland Woods	Joe
15	Flood Plains	Alluvial Basins & Terraces	0-5%	Alluvial Forests	Central

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SECTION 5

CHARACTERIZATION OF LAND USE

Land use activity within each of the 15 drainage areas was determined by utilizing the Land Activity File of the Tulsa Metropolitan Area Planning Commission (TMAPC). A description of the procedure used to characterize each test area will be given in this section.

The first step in the procedure was to establish the ridge lines of each drainage basin. This was accomplished by the use of U. S. G. S. quadrangle maps (7. 5 minute series) and the City of Tulsa Storm Drain Atlas (1" = 100'). The storm drain pipe network was transposed to base maps (1" = 600') developed by the TMAPC for a better definition of the storm drain system for the test areas.

The second step was to define the drainage areas in such a way that a computer program could be written to retrieve the land use data from the file. This was accomplished by outlining each drainage basin on Land Use Base Maps (1" = 200') of the TMAPC and by utilizing the appropriate parcel identification overlays. These overlays contain the census tract, planning block, and planning parcel numbers. The planning block was the level chosen to define each basin. Appendix F shows the watershed perimeters and the storm drain system within the watershed for each of the study areas. After each drainage basin had been defined by census tract and planning blocks, a program was written to sum various land use activities within each basin.

Data from the Land Activity File can be retrieved by using several different controls. The controls are codes that are attached to each parcel of land. The different codes assigned to each parcel are:

Commercial Statistical Area Code

Industrial Planning District Code

Predominant Use Group Code

Zoning Classification Code

Establishment Activity Code

Establishment Use Group Code

TMAPC normally retrieves land use data once a year for planning needs.

The commission retrieves land use data using the Establishment Use Group Code as its control. The TMAPC also makes a land use retrieval by study analysis units, using the Zoning Classification Code as the control.

Land activity retrieval for this project was accomplished by using the Establishment Use Group Code as the control for summing the various land activities. The alphanumeric use group code as set up by the TMAPC is a three digit (1--) numeric code. The first digit of the code represents a general land use classification. The second and third digits represent more specific land use activities within the particular general classes.

The code is an attempt to sort the various land activities into classifications which are economically or socially compatible. Present restrictions limit the TMAPC's utilization of the code for land use retrieval to the first two digits of the three digit code. All land activity data for this study was grouped into the following classifications by the present retrieval process.

The two digit Land Use Group Code is as follows:

1--Housing (Residential)
    100-single family housing
    120-two family housing
    130-multi-family housing
    140-mobile home housing
    150-group living
    170-not classified

2--Commercial
    210-retail and personal service
    220-intensive and extensive commercial recreation
    230-business service
    270-vacant commercial structure

3--Industrial
    310-low or limited nuisance activity
    320-wholesale, warehouse, and trucking activities
    340-substantial nuisance activity
    350-hazardous or noxious activity (includes extractive industries)

- 360-non-manufacturing activity
- 370-vacant industrial structure

4--Institutional
- 410-educational
- 420-health and welfare
- 430-cultural or social center
- 440-governmental
- 450-philanthropic and non-profit organization
- 460-church or cemetery
- 470-military

5--Transporation, Communication, Utility, and Right-of-Way
- 510-transportation
- 520-communication
- 530-utility
- 540-rights-of-way and/or utility easements
- 550-other utilities, communications, and sanitary services

6--Open Space and Recreation
- 610-open space
- 620-recreation outdoor land
- 630-recreation outdoor water
- 640-recreation indoor public facility

7--Agriculture
- 710-cropland
- 720-grazing and improved pasture
- 730-timberland
- 740-special farms

8--Unused Space and Accessory Buildings
- 810-water area
- 830-marginal land
- 840-vacant urban land
- 850-disposal areas
- 860-accessory buildings

The computer output from the retrieval based on TMAPC's Establishment Use Group Code gives the following reliable information:

Residential Land Activity
- Household units

Acres
Density (household units/residential area)

Commercial Land Activity
Acres
Total number of establishments
Number of parcels

Industrial Land Activity
Acres
Floor area

Public, Quasi-Public, Utilities, Open Space, and Agriculture
Acres

The summation of the above land use activities should give the total area within each drainage shed minus the amount of land devoted to roads and streets. Only the land devoted to large expressway systems has parcel numbers assigned.

The totals of the land activities within each test area had to be adjusted to account for the streets and for the divisions caused by the true ridge lines. The total amount of land devoted to streets was determined by measuring the length and width of the streets as shown on the 1" = 600' base maps of the TMAPC. Portions of the large tracts divided by ridge lines were either added or deleted by measuring the portion of land in question on TMAPC's 1" = 200' Land Use Base Maps.

The adjusted Land Use Activities by major groups are summarized in Tables 14 and 15. The population, drainage, and street characteristics are shown in Table 16, Table 17, and Table 18, respectively.

TABLE 14

LAND USE ACTIVITIES IN ACRES BY MAJOR USE GROUPS WITHIN THE FIFTEEN TEST AREAS, TULSA, OKLAHOMA

Test Area No.	Acres									
	Res.	Com.	Ind.	Inst.	Trans.	Open Space	Unused Space	Arterial Streets	Other Streets	Total
1	29	50	325	1	10	0	170	48	53	686
2	84	62	1	0	4	68	2	15	41	277
3	311	5	0	23	0	19	88	13	92	550
4	234	179	172	53	28	8	50	55	159	938
5	268	10	1	33	15	50	30	20	80	507
6	120	12	129	2	9	0	11	8	77	368
7	128	3	0	18	0	0	1	3	44	197
8	109	13	10	3	7	0	9	30	30	211
9	30	7	0	0	0	0	3	7	17	64
10	33	32	0	4	1	0	32	39	65	206
11	367	16	41	15	3	5	28	48	292	815
12	0	0	3	0	103[a]	107[b]	0	0	0	213
13	160	0	0	6	0	0	5	11	31	212
14	71	0	0	0	0	172	0	12	8	263
15	52	0	0	1	0	0	5	0	16	74

[a] 103 Acres of airport runways and supporting paved areas.

[b] 107 Acres of grassland adjacent to runways.

TABLE 15

PERCENTAGE OF LAND DEVOTED TO MAJOR USE GROUPS IN THE FIFTEEN TEST AREAS, TULSA, OKLAHOMA

Test Area No.	Percent								
	Res.	Com.	Ind.	Inst.	Trans.	Open Space	Unused Space	Arterial Streets	Other Streets
1	4.23	7.28	47.35	0.15	1.46	0.00	24.77	6.99	7.72
2	30.32	22.38	0.36	0.00	1.44	24.55	0.72	5.42	14.80
3	56.54	0.91	0.00	4.18	0.00	3.46	16.00	2.36	16.73
4	24.94	19.08	18.34	5.65	2.98	0.85	5.33	5.86	16.95
5	52.85	1.97	0.20	6.51	2.96	9.86	5.92	3.94	15.78
6	32.60	3.26	35.05	0.54	2.45	0.00	2.99	2.17	20.92
7	64.97	1.52	0.00	9.14	0.00	0.00	0.51	1.52	22.33
8	51.66	6.16	4.74	1.42	3.32	0.00	4.27	14.22	14.22
9	46.86	10.93	0.00	0.00	0.00	0.00	4.69	10.93	26.55
10	16.02	15.53	0.00	1.94	0.49	0.00	15.53	18.93	31.55
11	44.99	1.96	5.03	1.84	0.37	0.61	3.44	5.88	35.80
12	0.00	0.00	1.41	0.00	48.36	50.23	0.00	0.00	0.00
13	75.46	0.00	0.00	2.83	0.00	0.00	2.36	5.19	14.62
14	26.99	0.00	0.00	0.00	0.00	65.39	0.00	4.56	3.04
15	70.25	0.00	0.00	0.00	0.00	0.00	6.76	0.00	21.62

TABLE 16

POPULATION CHARACTERISTICS OF THE FIFTEEN TEST AREAS

Test Area No.	Total Living Units	Population	Population Estimator People/Unit	Residential Area Acres	Residential Density People/Res. Acre	Total Area Acres	Average Density People/Acre
1	100	350	3.50	29	12.07	686	0.51
2	369	1100	3.00	84	13.09	272	4.04
3	1147	3925	3.42	311	12.62	550	7.13
4	1122	3625	3.23	234	15.49	938	3.86
5	1765	4525	2.56	268	16.88	507	8.93
6	501	1200	2.37	120	10.00	368	3.26
7	616	2275	3.70	128	17.77	197	11.55
8	715	2400	3.35	109	22.02	211	11.37
9	267	875	3.26	30	29.17	64	13.67
10	425	885	2.08	33	26.82	206	4.30
11	3396	2800	2.30	367	21.25	815	9.57
12	0	0	0.00	0	0.00	223	0.00
13	168	500	3.01	160	3.13	212	2.36
14	77	250	3.01	71	3.52	263	0.95
15	282	830	2.95	52	15.96	74	11.22

TABLE 17

DRAINAGE CHARACTERISTICS OF THE TEST AREAS[a]

Test Area No.	A	L	L_c	H	S_c	SL	C	FF	$G \times 10^2$	R_n
1	686	9050	6000	113	0.011	3.19	30	0.83	1.07	.034
2	272	4230	2040	92	0.011	3.48	55	2.85	0.95	.033
3	550	6890	3000	186	0.009	3.82	27	2.66	1.41	.054
4	938	9260	4800	126	0.010	2.89	51	1.77	1.00	.029
5	507	11200	4800	140	0.013	3.29	30	0.96	2.16	.071
6	368	2170	3600	91	0.009	2.19	24	1.24	0.55	.012
7	197	4500	2100	85	0.013	2.89	32	1.94	1.52	.044
8	211	4800	1800	95	0.013	1.67	37	2.84	2.99	.050
9	64	2600	1380	60	0.011	1.55	31	1.47	3.61	.056
10	206	6350	3300	140	0.032	2.26	74	0.82	4.69	.106
11	815	9000	4200	162	0.007	1.83	41	2.01	2.24	.041
12	223	5710	2400	58	0.007	0.75	46	1.68	4.53	.034
13	212	7840	2600	140	0.015	4.60	23	1.37	2.54	.117
14	263	6400	3480	171	0.014	4.25	11	0.95	2.24	.095
15	74	2700	1600	30	0.012	0.78	38	1.26	3.21	.025

[a] Legend:

A = Area, acres.
L = Length of the main stream, feet.
L_c = Length of the main stream from the sampling site to the point nearest area centroid, feet.
H = Fall of the watershed, feet.
S_c = Average main channel slope, feet per foot.
S_l = Average land slope, percent.
C = Impervious cover, percent.
FF = Form factor = $43,560\ A/(L_c)^2$, dimensionless.
G = Geometry number (G)

$$= \frac{(L)\,(H)}{(43,560)\,(A)\,(S_l)}, \text{ dimensionless.}$$

R_n = Relief number $= \frac{(L)\,(H)}{A}$, dimensionless.

TABLE 18

STREET CHARACTERISTICS WITHIN THE FIFTEEN TEST AREAS

Test Area No.	Total Area of Streets and Easements[a] Acres	Estimated Area of Pavement Acres	Arterial Streets		Other Streets		Ratio of Streets to Total Area			
							Acres/Acre		Miles/Acre	
			Acres	Miles[b]	Acres	Miles[c]	Arterial	Other	Arterial	Other
1	101	65	48	3.43	53	8.03	0.070	0.077	0.0050	0.012
2	56	32	15	1.21	41	6.20	0.055	0.151	0.0044	0.023
3	105	56	13	1.07	92	13.80	0.024	0.167	0.0019	0.025
4	214	124	55	4.52	159	23.88	0.059	0.169	0.0048	0.025
5	100	56	20	1.63	80	14.69	0.039	0.158	0.0032	0.029
6	85	46	8	0.62	77	11.62	0.022	0.209	0.0017	0.032
7	47	24	3	0.26	44	6.58	0.015	0.223	0.0013	0.033
8	60	39	30	2.48	30	4.49	0.014	0.142	0.0012	0.021
9	24	10	7	0.60	17	2.51	0.011	0.266	0.0009	0.039
10	104	104	39	3.21	65	9.78	0.019	0.316	0.0016	0.047
11	340	179	48	4.00	292	46.66	0.059	0.358	0.0049	0.057
12	0	0	0	0.00	0	3.39	0.000	0.000	0.0000	0.015
13	42	24	11	0.88	31	4.70	0.052	0.146	0.0042	0.022
14	20	14	12	1.14	8	0.93	0.046	0.030	0.0043	0.004
15	16	10	0	0.00	16	1.64	0.000	0.216	0.0000	0.022

[a] Calculated from land use retrieval information.
[b] Calculated by measurements taken from land activity maps.
[c] Estimated by assuming an average street width of 55 feet (this includes pavement and easements).

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SECTION 6

ENVIRONMENTAL CONDITIONS

In 1968 the Tulsa City-County Health Department conducted a Community Block Survey in Tulsa. The purpose of the survey was to delineate the general environmental conditions of the Tulsa area. An analysis of the data resulting from this survey provides a method of locating environmental conditions of communicable disease within a specific community. Also, with this data and additional census block data, a community can be stratified into socioeconomic areas.

The environmental factors included in the survey were land use, exterior housing quality, water supply, human waste disposal, refuse storage, rubble accumulations, junked cars, dilapidated sheds, vacant lot sanitation, poor drainage areas, vector harborage, and the presence of livestock, poultry, and dogs.

Definitions of Environmental Factors

Environmental conditions or factors have different meanings to various groups and agencies. For example, the TMAPC has many business and commercial categories which it classifies into several use groups. The health agencies, on the other hand, normally make only two classifications for business and commercial activities: food and non-food.

For the most part, the survey followed the procedures set forth in the manual "Community Block Survey and Socioeconomic Stratification" (9) published by the Public Health Service. Below are the definitions of the data items collected by the survey.

Land Uses - This factor is divided into nine classifications which are standard in Public Health Service procedures. These classifications are:

Residential
Business and Commercial
  a) Food
  b) Non-food
Industrial
  a) Food processing
  b) Non-food manufacturing
Transportation Services
Public, Cultural, Educational, and
  Related Uses

Parks and Recreational
Utilities
Agriculture
Miscellaneous

The business and commercial classification and the industrial classification have each been divided into two subclassifications, because food using and processing establishments produce organic wastes. These wastes usually present a greater public health problem than waste materials from other types of firms.

Exterior Housing Quality - This factor is divided into three categories: good (sound), fair (deteriorating), and poor (dilapidated). The deterioration of the exterior of residential structures is classified and used as a basic factor in stratifying a community into socioeconomic frames. The condition of housing is also a basic environmental sanitation factor.

A residential structure should have at least 150 square feet of floor space. The window space should equal at least 10 percent of the floor area. A house is classified as sound if it is free from decay and structurally safe. The exterior walls are level and plumb. The surface of a good structure is composed of an acceptable material as judged by recognized building code standards.

Human Waste Disposal - When untreated human waste is exposed to the elements, to a water source, to animals, or to insects, a human waste disposal deficiency exists. Examples of exposed human waste are outdoor privies, improperly operated septic tanks, cesspools, and frostproof toilets.

Refuse Storage - Refuse is solid waste including garbage and rubbish. Garbage consists of all putrescible material except body wastes. Rubbish is non-putrescible waste and includes debris, tin cans, bottles, paper, grass cuttings, paper boxes, short pieces of lumber scraps or other building materials, and tree limbs not over 3 feet in length. No piece classified as rubbish weights over 50 lbs.

Suitable refuse storage exists on a premise if all refuse (garbage and rubbish) is stored in a container which meets the requirements of local ordinances and authorities.

Rubble Accumulations - Solid waste which is larger and heavier than rubbish is classified as rubble. Examples of rubble are: large brushwood, large and/or long cardboard boxes, large and/or heavy yard trimmings, discarded fence posts, bed springs, large furniture, and water heaters. Improper rubble storage exists when any rubble is on a premise.

Junked Cars - An abandoned automobile is a special category of rubble. A junked car is improperly stored if it is outside a conforming structure anywhere in a residential area or in a business or commercial area not zoned for this type of storage.

Dilapidated Sheds - Outbuildings that have deteriorated past their intended usefulness or original purpose are considered to be dilapidated sheds. Their structures are decayed and not weatherproof. A shed of this type is a fire hazard and a rodent harborage. It also detracts from the appearance of the premises and the neighborhood.

Vacant Lot Sanitation - A vacant lot in an urban community is an undeveloped lot which has an area the size of other lots which are developed in the neighborhood. If there is no indication of a standard size, a street frontage of 100 linear feet per vacant lot is used to estimate the number of vacant lots in a block. A weeded vacant lot is one that has pollinating weeds or brush and weeds over 12 inches high. No sanitary deficiencies must be present. A lot with these conditions is classified as a fair or moderate vacant lot. A vacant lot which has any refuse, trash, rubble, or carrion on its premises is classified as a poor vacant lot.

Drainage - The area is rated as to the existence and form of its drainage net. Poor drainage exists when the surface has depressions which hold water for three or more days following a rain. The channels are classed as either open channels or enclosed conduits, such as storm sewers. Open channels are further classified as to type of lining, such as concrete or earthen.

Presence of Livestock, Poultry, and Dogs - The type and number of livestock, the number of poultry, and the number of dogs observed in the area survey are recorded. Dogs are further classified as controlled or stray. The "controlled" classification is assigned to dogs which are kept in an enclosure.

Survey Procedures - The procedure followed in gathering the data was a block by block "windshield" survey. All housing conditions and environmental deficiencies were recorded and then coded on TMAPC's Land Use Maps. These data items were evaluated and summarized by block and census tracts.

The block summaries were recorded on computer cards and stored. This information was thus available for other studies and was used to categorize the 15 test areas in this project.

The environmental conditions or variables within the test areas were determined by summing the block totals for the particular drainage basins. Table 19 presents these totals for each of the 15 test areas.

Normal socioeconomic stratification by the Public Health Service is accomplished by evaluating and utilizing slow-to-change factors such as the housing conditions, housing prices, family incomes, and education level of adults within the community of interest (9). The degree of deterioration of the exterior surfaces of residential structures is a consistent, reliable indicator of the socioeconomic status--the higher the density, the lower the indicated socioeconomic status.

The procedure followed in stratifying a community into socioeconomic levels involves the determination and weighting of three or more "indicators." The indicators used are: (1) housing condition, (2) housing price, (3) crowding, (4) family income, and (5) education level.

This procedure is not valid for large areas. Large areas have to be subdivided to enable the groupings of existing housing and other environmental conditions into uniform classes. Also, a more complete evaluation of socioeconomic areas should involve physical health standards and a knowledge of the culture of the local people.

Environmental Index

Since the above procedure is not applicable to large areas and could not be extended for use in commercial or industrial areas, a method was devised by the author of this study for determining the general environmental conditions of the fifteen test areas. An Environmental Index (EI) was calculated for each area, as follows:

$$\text{Environmental Index (EI)} = f\,(\text{housing condition, vacant lot condition, parcel deficiencies}) \qquad (6\text{-}1)$$

Assuming that the parcel deficiencies should be weighted more heavily than the housing conditions and that the housing conditions should be weighted more heavily than the vacant lot conditions:

$$EI = \frac{2A + B + 3C}{6} \qquad (6\text{-}2)$$

Where: $$A=\frac{\text{Total Housing Structures}}{G + 2F + 3P}$$

Note: G = no. of good houses
F = no. of fair houses
P = no. of poor houses

$$B=\frac{\text{Total Vacant Lots}}{G + 2F + 3P}$$

Note: G = no. of good vacant lots
F = no. of fair vacant lots
P = no. of poor vacant lots

$$C=\frac{\text{Total Structures - Total Deficiencies}}{\text{Total Structures}}$$

Note: Total deficiences include the sum total of refuse, burners, rubble, lumber, old autos, poor sheds, livestock, poultry, and privies.

The above three factors (A, B, and C) are a measure of the general housing condition, the vacant lot condition, and the parcel deficiencies, respectively. Factors A and B vary from a low of 0. 33 to a high of 1. 00. Factor C varies from a negative number to 1. 00. The smaller numbers indicate poor environmental conditions.

Applying the above formula will result in an Environmental Index that varies from a negative number to a maximum of 1. 00. A value of 1. 00 denotes an area of all good houses, all good vacant lots, and no parcel deficiencies.

Not included in the above index are several other factors that, if used, would result in a better measure of the "general environmental condition of an area." Such items are: air pollution sources; density of population and structures; point sources of water pollution; parks; noise level; and traffic volume. If these data items were available and each could be expressed as a weighted numerical coefficient, a better EI could be developed. Factor analysis was used in an attempt to refine the EI; results are discussed in Section 10.

Applying the above formula to the data of Table 19, an EI for each of the test areas was calculated. Table 20 presents these calculations with the resulting EI. Table 21 gives a percentage breakdown of the various categories shown on Table 19.

TABLE 19

NUMBER OF HOUSING AND PARCEL DEFICIENCIES WITHIN THE FIFTEEN TEST AREAS

Test Area No.	Housing							Vacant Lots				Deficiencies					
	Condition					Bus. Struct.											
	Total No.	Good	Fair	Poor	Total Units	Food	Other	Total No.	Good	Fair	Poor	Refuse	Burners	Rubble	Lumber	Old Autos	Poor Sheds
1	242	240	2	0	250	6	119	308	308	0	0	0	0	0	0	1	0
2	369	369	0	0	369	7	42	0	0	0	0	3	0	0	0	0	0
3	1147	1147	0	0	1147	3	5	85	68	17	0	0	0	0	0	0	0
4	1200	1199	1	0	1122	4	262	6	6		0	289	89	32	5	7	1
5	1413	1411	2	0	1765	5	48	16	16	0	0	11	8	6	2	1	0
6	476	287	149	40	501	6	48	18	10	5	3	121	101	27	10	11	3
7	599	599	0	0	616	0	2	7	7	0	0	10	10	7	0	0	0
8	674	672	2	0	715	5	8	7	7	0	0	194	43	11	4	6	1
9	247	150	80	17	265	3	9	23	13	0	10	109	95	52	17	7	25
10	267	222	38	7	2103	26	191	174	168	6	0	23	11	1	0	0	0
11	3130	656	1206	1268	3396	37	197	197	99	52	40	1934	1871	343	114	139	94
12	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
13	168	168	0	0	168	0	2	8	8	0	0	6	2	1	1	0	0
14	77	77	0	0	77	0	0	1	1	0	0	0	0	0	0	0	0
15	265	265	0	0	282	0	4	3	3	0	0	35	29	10	1	1	1

TABLE 20

CALCULATION PROCEDURE FOR THE ENVIRONMENTAL INDEX (EI) OF THE TEST AREAS

Test Area No.	Housing[a] 1 Total Housing	2 1G+2F +3P	3 A[b]	Vacant Lots[a] 4 Total Vac. lots	5 1G+2F +3P	6 B	Parcel Deficiencies 7 Total Structures	8 Total Def.	9 7-8	10 C	EI 11 $\frac{2A+B+3C}{6}$
1	242	244	0.99	308	308	1.00	367	1	366	1.00	1.00
2	369	369	1.00	0	0	1.00	418	3	415	0.99	0.99
3	1147	1147	1.00	85	102	0.83	1155	1	1154	1.00	0.97
4	1200	1201	1.00	6	6	1.00	1466	423	1043	0.71	0.86
5	1413	1415	1.00	16	16	1.00	1466	29	1437	0.98	0.99
6	476	705	0.68	18	29	0.62	530	277	253	0.48	0.57
7	599	599	1.00	7	7	1.00	601	27	574	0.96	0.98
8	674	676	1.00	7	7	1.00	687	259	428	0.62	0.81
9	247	358	0.70	23	43	0.53	259	307	-48	-0.19	0.23
10	267	319	0.84	174	180	0.97	484	35	449	0.93	0.91
11	3130	6872	0.46	197	350	0.56	3364	4501	-1137	-0.34	0.08
12	0	0	n.a.[c]	0	0	n.a.	0	0	0	n.a.	1.00[d]
13	168	168	1.00	8	8	1.00	170	10	160	0.94	0.97
14	77	77	1.00	1	1	1.00	77	0	77	1.00	1.00
15	265	256	1.00	3	3	1.00	269	77	192	0.71	0.86

[a] G=Good F=Fair P=Poor

[b] A=Housing Index (HI)

[c] Not applicable

[d] Test area no. 12 was assumed to have an EI of 1.00

TABLE 21

ENVIRONMENTAL CONDITIONS OF THE FIFTEEN TEST AREAS

Test Area No.	Housing Percent Good	Housing Percent Fair	Housing Percent Poor	HI[a]	Parcel Deficiencies Average Deficiencies Per Acre Refuse	Burners	Rubble	Lumber	Old Autos	Poor Sheds	Total[b]	EI[c]
1	99.2	0.8	0.0	.99	0.000	0.000	0.000	0.000	0.000	0.000	0.001	1.00
2	100.0	0.0	0.0	1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.99
3	100.0	0.0	0.0	1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.97
4	100.0	0.0	0.0	1.00	0.308	0.095	0.035	0.005	0.007	0.000	0.450	0.86
5	99.9	0.1	0.0	1.00	0.027	0.016	0.012	0.004	0.002	0.000	0.057	0.99
6	60.3	31.3	8.4	.68	0.329	0.274	0.060	0.027	0.030	0.008	0.778	0.57
7	100.0	0.0	0.0	1.00	0.051	0.051	0.035	0.000	0.000	0.000	0.137	0.98
8	99.7	0.3	0.0	1.00	0.920	0.204	0.052	0.019	0.028	0.004	1.230	0.81
9	60.7	32.5	6.8	.70	1.700	1.480	0.810	0.265	0.109	0.390	4.960	0.23
10	83.1	14.2	0.7	.84	0.114	0.053	0.005	0.000	0.000	0.000	0.199	0.91
11	21.0	38.5	40.5	.46	2.370	2.290	0.420	0.140	0.170	0.115	5.660	0.08
12	0.0	0.0	0.0	n.a.[d]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.00[e]
13	100.0	0.0	0.0	1.00	0.028	0.009	0.005	0.005	0.000	0.000	0.047	0.97
14	100.0	0.0	0.0	1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.00
15	100.0	0.0	0.0	1.00	0.460	0.392	0.135	0.013	0.013	0.013	1.040	0.86

[a] Housing index (HI)

[b] Total deficiencies per acre including fair and poor vacant lots.

[c] Environmental index (EI)

[d] Not applicable

[e] **Test area no. 12 was assumed to have an EI of 1.00**

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SECTION 7

SAMPLING INSTRUMENTS AND METHODS USED

The collection of storm water runoff samples required the use of several different types of instruments and methods. The methods and instruments used are described in the following:

Sampling Equipment

Standard procedures for manual sampling (grab sampling) were used when baseline samples or storm water runoff samples were collected. The bacteriological samples were collected in sterile plastic bags. The samples for chemical analysis were collected in one-half gallon plastic jugs.

A stationary, automatic-sampling method was used when a time series of samples was desired. The sampling apparatus used was unique. It was fabricated locally from commercially available components. The assembled device consisted of a peristaltic tube pump, inclined sequential sample container, voltage inverter, 12-volt battery, sampling probe, pressure diaphragm box, and pressure recorder. All of the components except the sampling probe and pressure box were enclosed in a semi-portable shelter which was secured against pilferage.

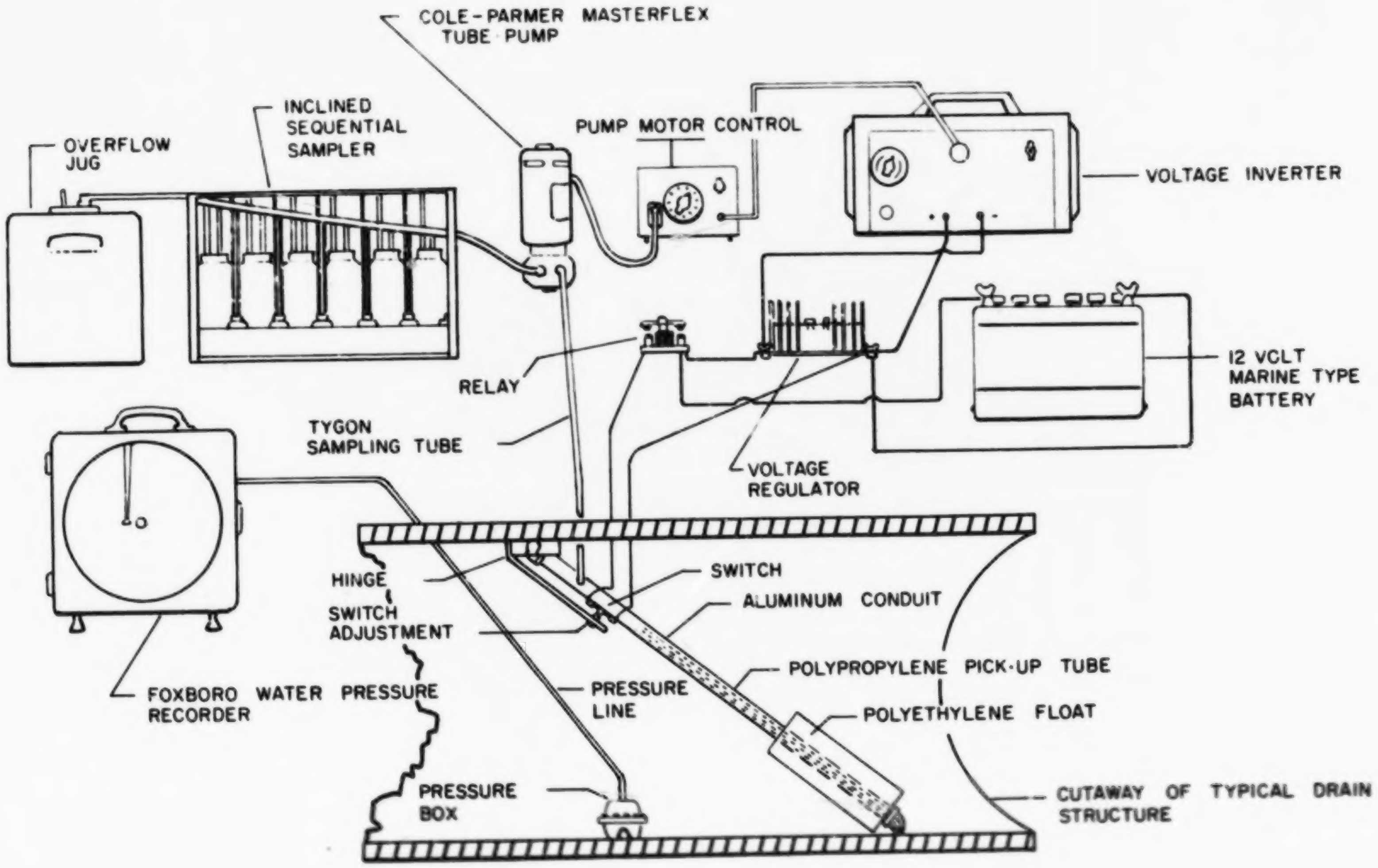
Shown schematically in Figure 6 is the mechanical arrangement of parts. The wiring diagram and parts list are shown in Figure 7. Figures 8 and 9 consist of detailed drawings of the inclined sequential sample container. Various views of the sampling equipment and installations are shown in Figures 10 through 15.

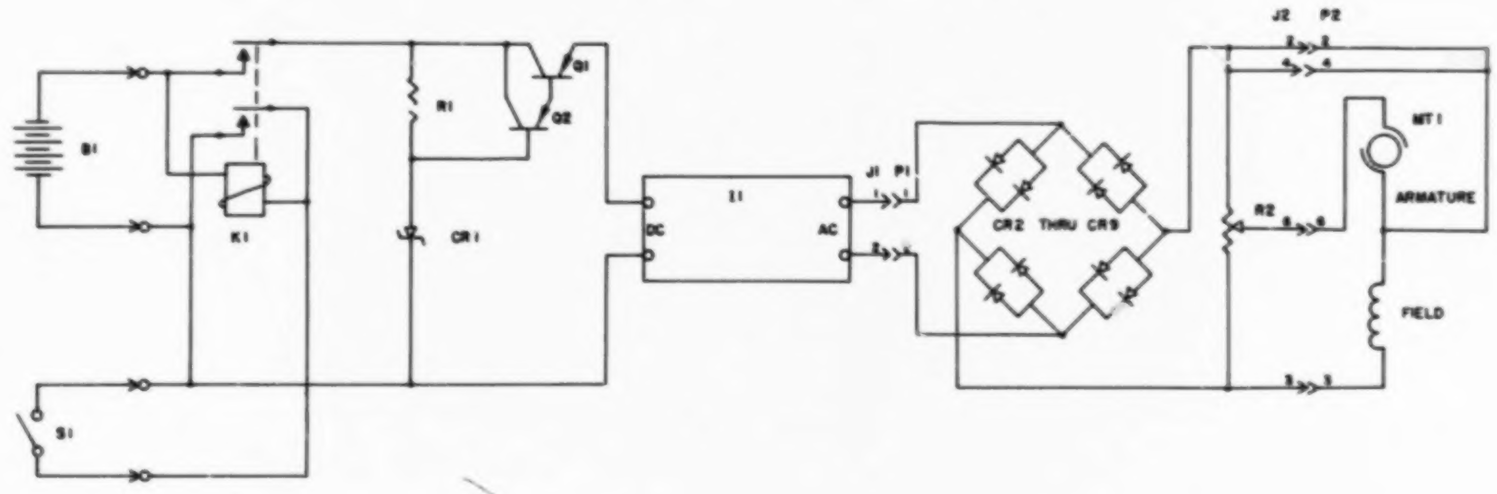
The inclined sequential sample container and overflow jug are connected to a peristaltic tube pump with "Tygon" tubing and a polyethylene quick disconnect. The inlet side of the tube pump is connected to a length of polyethylene tube which is inside a lightweight aluminum conduit. The aluminum conduit is also the float arm which activates the switch mechanism.

The switch-float mechanism consists of a polyethylene foam float connected to a length of aluminum conduit which is hinged at the top of the storm drainage structure. Attached to the aluminum conduit arm is a small micro-switch which is activated by a small metal arm

FIGURE 6

SCHEMATIC DIAGRAM OF STORM WATER SEQUENTIAL SAMPLING EQUIPMENT


COLE-PARMER MASTERFLEX TUBE PUMP
INCLINED SEQUENTIAL SAMPLER
OVERFLOW JUG
PUMP MOTOR CONTROL
VOLTAGE INVERTER
12 VOLT MARINE TYPE BATTERY
RELAY
TYGON SAMPLING TUBE
VOLTAGE REGULATOR
HINGE
SWITCH
SWITCH ADJUSTMENT
ALUMINUM CONDUIT
POLYPROPYLENE PICK-UP TUBE
POLYETHYLENE FLOAT
FOXBORO WATER PRESSURE RECORDER
PRESSURE LINE
PRESSURE BOX
CUTAWAY OF TYPICAL DRAIN STRUCTURE



PARTS LIST

REF. DESIGN	QUAN.	PART NUMBER DESCRIPTION	REF. DESIGN	QUAN.	PART NUMBER DESCRIPTION
I1	1	Tornado Power Inverter, 12VDC Input - 120VAC Output, Allied No 214499	Q1	1	2N2156 Transistor
B1	1	12V DC Battery	Q2	1	2N2580 Transistor
MT1	1	Cole-Parmer Masterflex Tube Pump, Model No 7015	J1	1	Two Prong AC Receptacle – Part of I1
S1	1	Cherry Electric Spdt, 15A At 125/230V AC, Switch	P1	1	Two Prong AC Plug
K1	1	PR7DY Potter Brumfield, Relay 12V DC	J2	1	S-2406 DB, 6 Pin Connector, Cinch Jones
R1	1	470 OHM 10% Resistor	P2	1	P-406 DB, 6 Pin Plug, (Part of MP5
R2	1	200 OHM 100Watt Rheostat, Ohmite No 0452		1	CU-728 Bud Chassis
CR1	1	1N758 Diode		1	870 Terminal Strip, H.H. Smith
CR2 - CR9	8	1N2069 Diode		1	905 Dial Plate, Waldon

FIGURE 7
WIRING DIAGRAM AND
PARTS LIST OF PUMP UNIT

FIGURE 8

INCLINED SEQUENTIAL SAMPLE CONTAINER

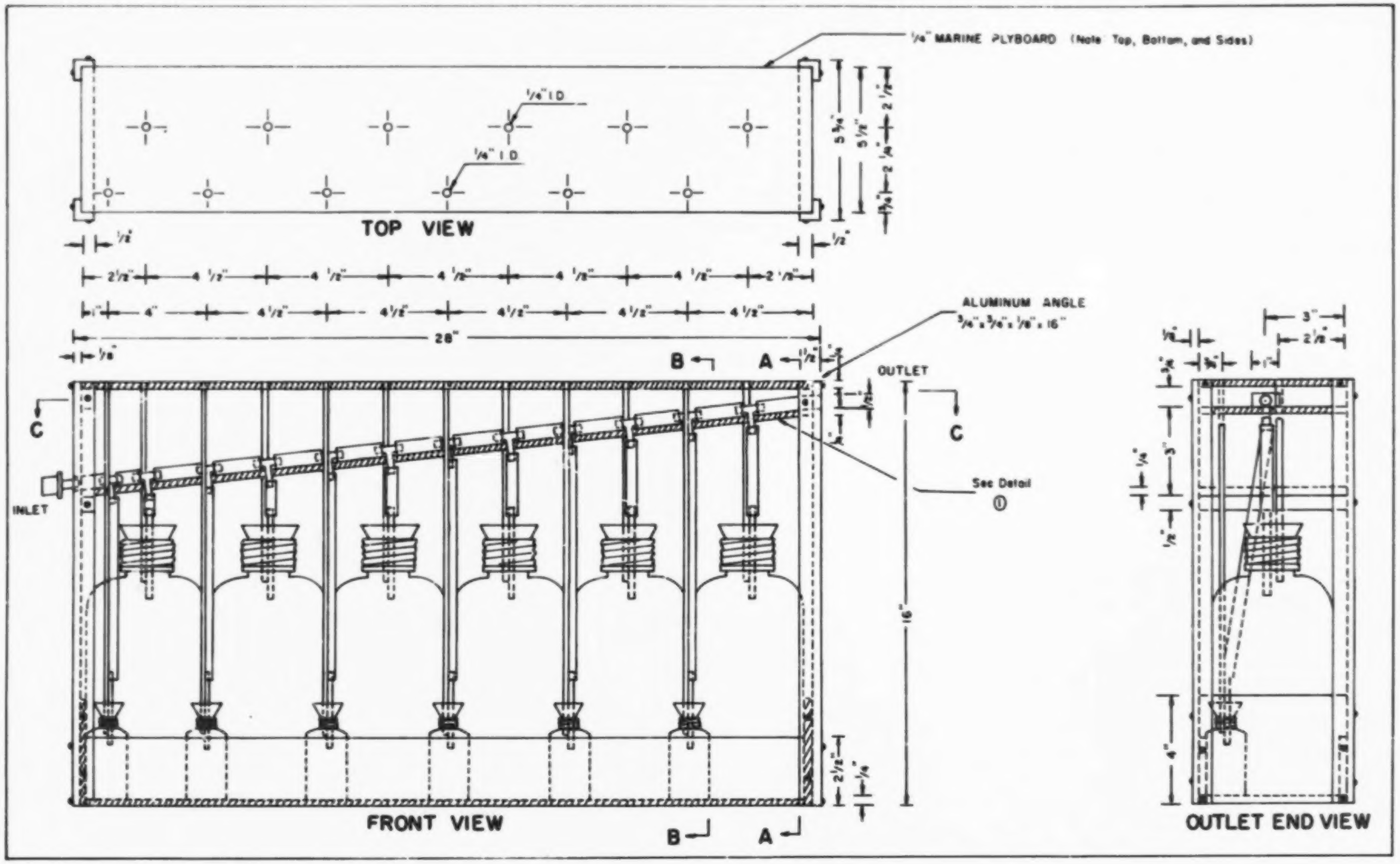
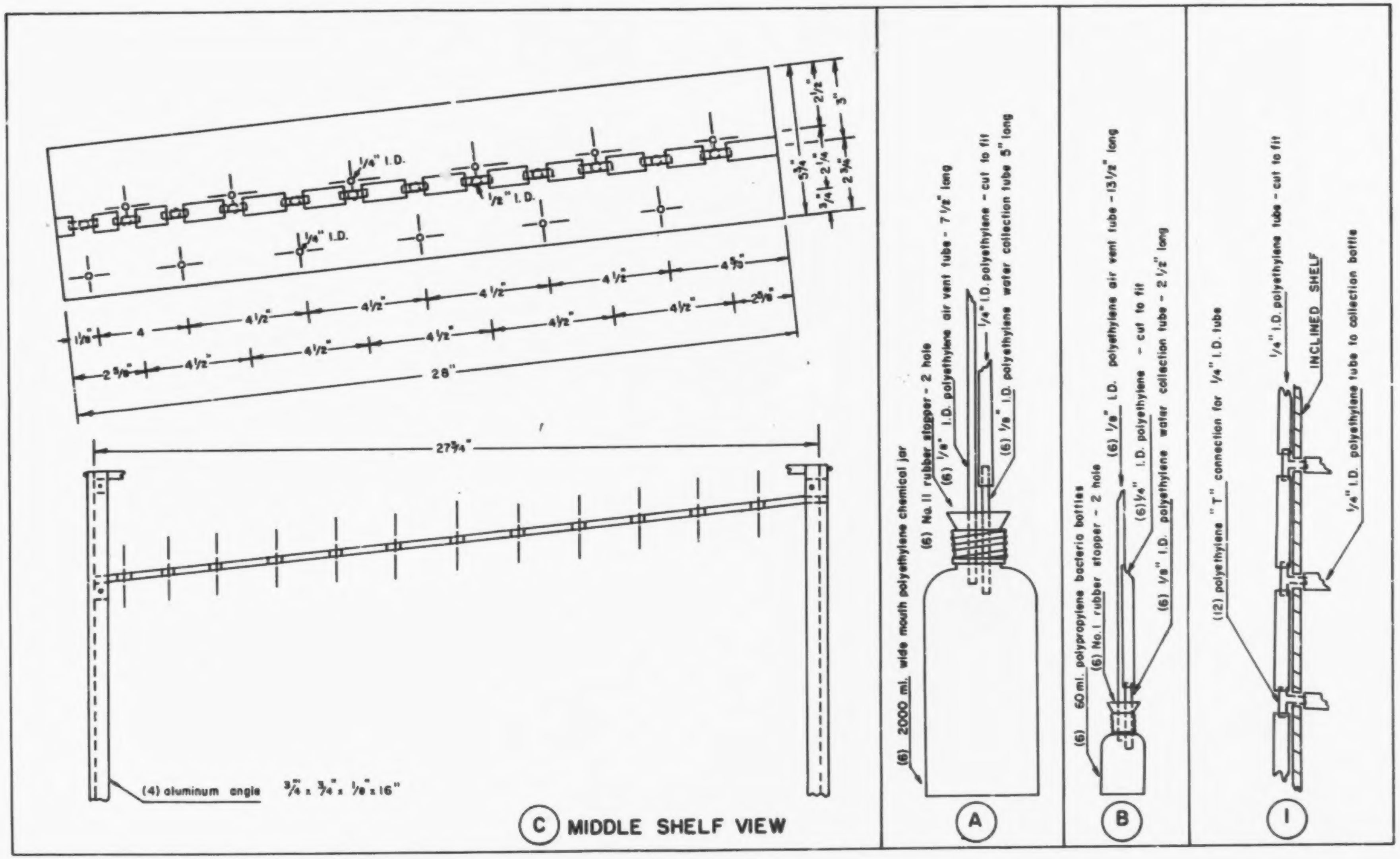

1/4" MARINE PLYBOARD (Note Top, Bottom, and Sides)
1/4" I.D.
1/4" I.D.
TOP VIEW
5 3/4"
5 1/2"
2 1/2"
2 1/4"
3/4"
1/2"
1/2"
2 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
2 1/2"
1"
4"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
28"
1/8"
ALUMINUM ANGLE
3/4" x 3/4" x 1/8" x 16"
B
A
1 1/2"
OUTLET
C
C
INLET
See Detail
①
16"
2 1/2"
1/4"
FRONT VIEW
B
A
3"
2 1/2"
1/2"
3/4"
1"
3"
1/4"
1/2"
4"
OUTLET END VIEW

FIGURE 9

DETAIL PLANS OF INCLINED SEQUENTIAL SAMPLE CONTAINER


1/4" I.D.
1/2" I.D.
1/4" I.D.
5 3/4"
3/4"
2 1/4"
2 3/4"
2 1/2"
3"
1/8"
4
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 5/8"
2 5/8"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
4 1/2"
2 5/8"
28"
27 3/4"
(4) aluminum angle 3/4" x 3/4" x 1/8" x 16"
C MIDDLE SHELF VIEW
(6) 2000 ml. wide mouth polyethylene chemical jar
(6) No. 11 rubber stopper - 2 hole
(6) 1/8" I.D. polyethylene air vent tube - 7 1/2" long
1/4" I.D. polyethylene - cut to fit
(6) 1/8" I.D. polyethylene water collection tube 5" long
A
(6) 60 ml. polypropylene bacteria bottles
(6) No. 1 rubber stopper - 2 hole
(6) 1/8" I.D. polyethylene air vent tube - 13 1/2" long
(6) 1/4" I.D. polyethylene - cut to fit
(6) 1/8" I.D. polyethylene water collection tube - 2 1/2" long
B
(12) polyethylene "T" connection for 1/4" I.D. tube
1/4" I.D. polyethylene tube - cut to fit
INCLINED SHELF
1/4" I.D. polyethylene tube to collection bottle
I

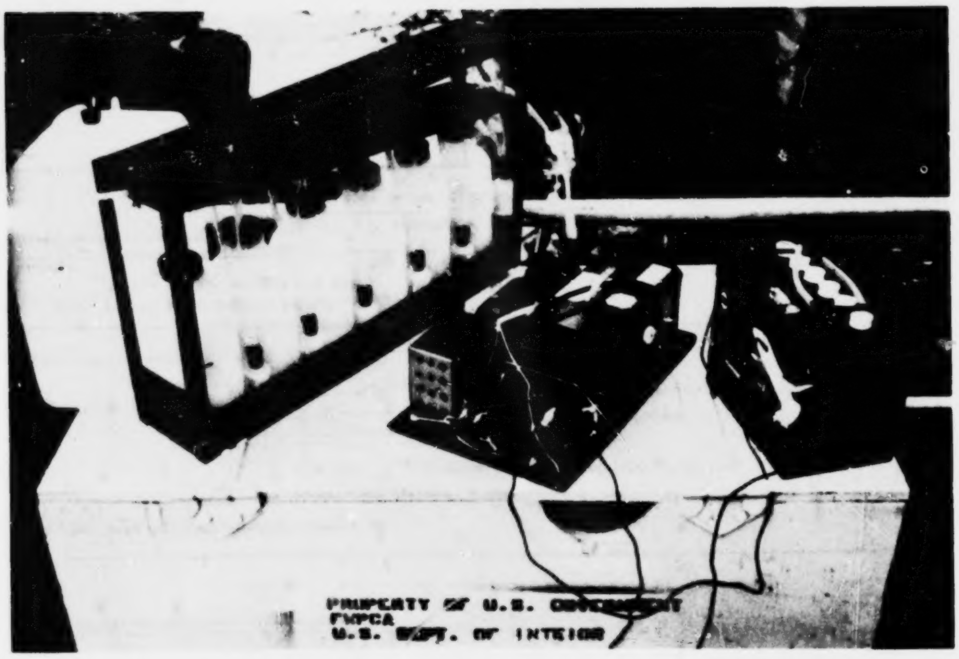

PROPERTY OF U.S. GOVERNMENT
FWPCA
U.S. DEPT. OF INTERIOR

FIGURE 10. Sampling equipment--from left to right: overflow jug, inclined sequential sample container pump and control unit, and 12VDC marine battery

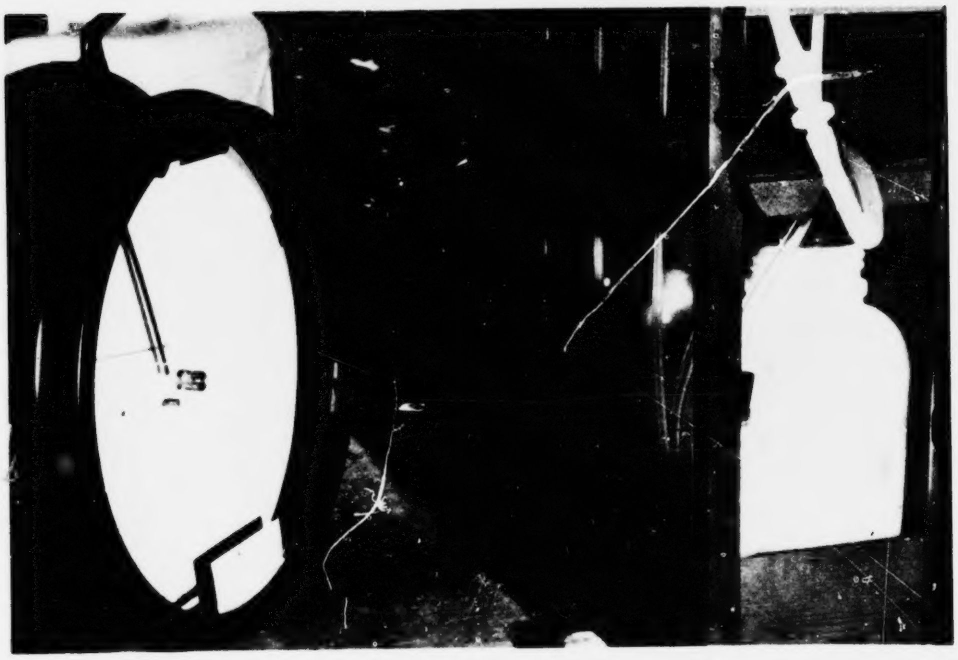


FIGURE 11. Bottom of enclosure showing pressure recorder, overflow jug, and inclined sequential sample container

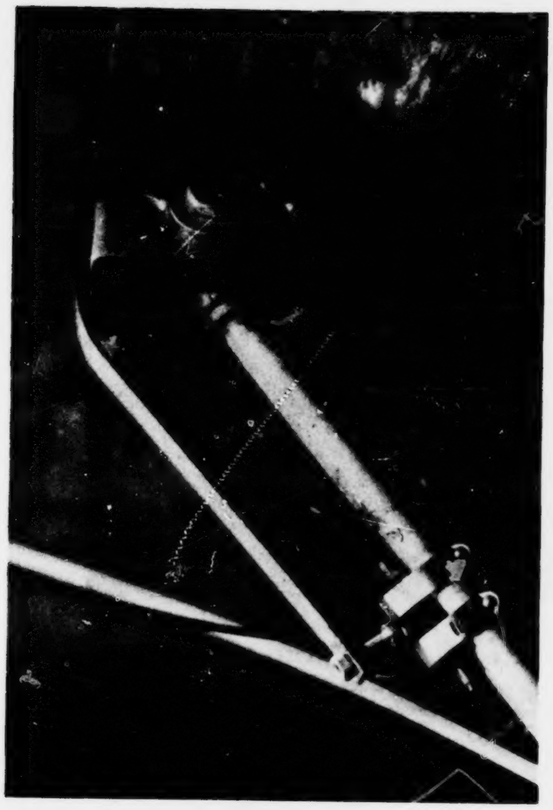


FIGURE 12.

Top of sampling probe showing hinge box fastened to top of drainage structure with "on" switch and switch arm

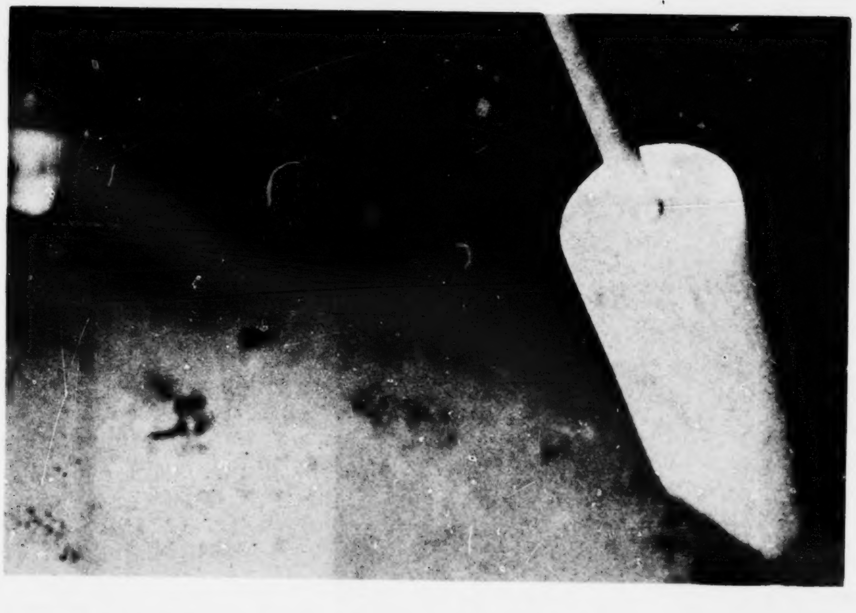


FIGURE 13. Sampling probe float and pressure box

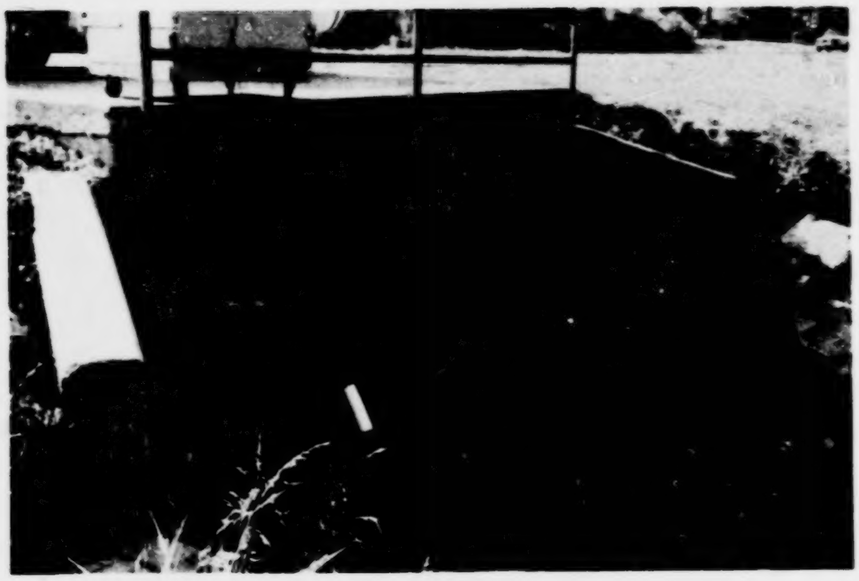


FIGURE 14. Equipment enclosure and sampling probe located at sampling site for Test Area No. 3.

FIGURE 15.

Service truck, enclosure, and sampling probe at sampling site for Test Area No. 10.

extending down from the hinge.

As the storm water flow lifts the float, the micro switch activates the relay, the pump turns on, and the sampling starts. With this arrangement, it was possible to collect separate bacteriological samples and have each sample composited over a predetermined time period. Five such "sampling stations" were fabricated and used on the project.

The principle of operation of the inclined sequential sample container is very simple. As the water is lifted by the peristaltic pump and enters the inlet side of the container, the sampler composites an amount of water into the first bottle, which is a 60 ml sample bottle, until it is full. The water then travels up the inclined tube to the next bottle, which is a 2000 ml chemical collection bottle, and water is composited until it too is full. This sequence of filling the polyethylene bottles is repeated until all the bottles in the sequential sample container are filled. Once this container is full, the water is then composited in an air vented 5 gallon capacity overflow bottle.

It is possible to collect a series of separate bacteriological and chemical samples each composited over a given time period according to flow rate and bottle size. The only mixing that occurs involves the amount of water displaced in the air vent tube as the sample moves up the incline due to the pressure differential between bottles. The pressure differential is a function of the slope of the inclined tube and can be kept small by selecting an air vent tube of small inside diameter.

Below is a breakdown of the unit cost of the stationary automatic sampling station used on the project.

Item	Cost
12VDC Marine battery	$ 25.00
Voltage inverter	47.00
Tube pump	83.00
Pump motor control voltage regulator, relay, and switch	30.00
Inclined sequential container	26.00
Tubing, float, float arm, float arm hinge, and wire	15.00
Enclosure, chain, lock	30.00
Pressure recorder	213.00
Pressure diaphragm box	65.00
Pressure line and connectors	4.00
Labor: Assembly time of components--15 hours at $10.00/hour (includes overhead)	150.00

Installation time in field at sampling sites--4 hours at \$10.00/hour (includes renting of necessary equipment for installation)	40.00
Total unit cost of sampling station	\$728.00

The number of drainage sheds investigated made it imperative that more than five drainage areas be sampled during each runoff period. Therefore, three portable automatic sampling systems were utilized. Pumps and sample containers in these systems were housed in small plyboard boxes which were placed at the sampling sites after the rainfall events started.

Runoff Sampling Methods and Procedures

The 15 drainage sheds were originally divided into three groups of 5 test areas. Each group was located within the same general area to expedite sample collection. Samples were collected at each site during each quarter of the "water year" or annual cycle of rainfall. The planned sampling schedule was not rigorously followed throughout the entire project because of the lack of rainfall and runoff during the dry months.

The five sampling stations and instruments were placed at sites in Group A in September, and samples were collected at these sites during September and October 1969. In November the sampling stations were moved to sites in Group B; they were subsequently moved to Group C in January. In April 1969, it was concluded that the 5 semi-stationary automatic sampling stations should remain at these sites for the remainder of the project.

To obtain composite samples at the other ten sites, 3 portable plyboard instrument enclosures were fabricated to house the sampling gear. The instruments were normally placed out after the start of the rainfall to operate at the beginning of the runoff period. The composite time could be adjusted to have a period of "pump-on time" and a period of "pump-off time". The sample containers in the three portable enclosures could be changed to obtain a set of time series composite samples during runoff periods.

Bacteriological samples were collected in sterile plastic bags. The sampling sequence for the bacteriological samples was: one sample when the pump was placed in operation, another sample when the composite jug was changed, and the third sample when the pump and enclosure were retrieved from the site.

During the course of the project, "grab" samples were collected when more samples were needed from a particular drainage shed. "Baseline" samples were also collected by the "grab" sampling procedure. Vandals hampered the operation of the project. Several of the semi-stationary sampling stations were broken open and some of the equipment damaged. This caused important data losses on some of the watersheds.

The biggest problem was obtaining stage readings and velocity measurements of the runoff flows. Originally, pressure recorders used on the project were calibrated for 120 inches of water at full scale.

The initial hydrograph records produced at the sites utilized only a fraction of the chart scale. Therefore, it was necessary to recalibrate the pressure recorders to obtain more sensitive readings. In February, the pressure recorders were recalibrated to obtain 60 inches of water at full scale.

Since only five recorders and pressure diaphragm boxes were purchased for the project, it was necessary to relocate these instruments during the project period. Stream flow hydrographs were only obtained from several of the test areas investigated.

Laboratory Methods and Procedures

After the storm water runoff samples were obtained at the field sampling sites, they were transported to the laboratory for analysis. The samples were stored and analyzed in accordance with Standard Methods for the Examination of Water and Waste Water, Twelfth Edition (10).

The first action was to divide the samples into two portions and to "fix" and store one portion for future analysis. The second portion was used for BOD and bacteria analysis. Bacteriological samples were examined for total coliform, fecal coliform, and fecal streptococcus by the membrane filter (MF) technique with the use of M-Endo, MFC, and KF Streptococcus media, respectively.

Analyses for Total Organic Carbon (TOC) were performed by the Civil Engineering Department, University of Arkansas. Preceding the shipment of these samples to the University of Arkansas, the samples were "fixed" with sulfuric acid for preservation. The shipment, normally by bus, was accomplished on the day of collection. Analysis was performed with the use of a Beckman TOC Analyzer (Model 915).

Listed below are the various pollution parameters measured on each sample.

Bacteriological

Total Coliform (T. Col.)
Fecal Coliform (F. Col.)
Fecal Streptococcus (F. Strep.)

Organic

Biochemical Oxygen Demand (BOD)
Chemical Oxygen Demand (COD)
Total Organic Carbon (TOC)

Nutritional

Organic Kjeldahl Nitrogen (N)
Soluble Orthophosphate (PO_4)

Solids

Total Solids (TS)
Suspended Solids (SS)
Dissolved Solids (DS)
Volatile Suspended Solids (VSS)
Volatile Dissolved Solids (VDS)

Other

pH
Chloride (Cl)
Specific Conductance

The number of reliable measurements of each parameter for each test area is shown in Table 22. Many more observations were made than are shown in the table, but a number were discarded as unreliable due to poor analytical results. Table 23 shows the number of samples collected from each test area by event number and date.

TABLE 22

NUMBER OF RELIABLE OBSERVATIONS OF EACH PARAMETER FROM EACH TEST AREA[a]

Test Area No.	Parameter Symbol															
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}	Y_{13}	Y_{14}	Y_{15}	Y_{16}
1	32	16	33	30	17	14	17	17	30	30	29	30	30	36	30	17
2	20	15	25	26	16	11	16	16	26	26	25	26	24	26	26	16
3	36	27	44	39	31	28	31	31	39	39	39	39	42	48	48	31
4	42	44	45	44	44	34	29	29	39	39	39	39	39	44	36	25
5	45	50	49	47	49	36	38	34	43	43	41	43	40	49	32	31
6	15	14	15	15	15	13	15	15	15	15	15	15	15	15	15	15
7	38	28	49	37	26	22	26	26	41	41	39	41	41	49	43	26
8	13	11	13	13	13	13	13	13	13	13	13	13	13	13	13	13
9	16	15	16	13	15	11	15	15	15	15	15	15	15	15	15	15
10	33	33	30	32	31	23	26	26	30	30	30	30	29	31	24	24
11	25	22	25	26	26	20	26	26	26	26	26	26	26	26	26	26
12	29	27	29	28	28	23	28	28	28	28	28	28	28	28	28	28
13	13	15	23	28	19	17	19	19	28	28	28	28	28	28	28	19
14	17	18	18	18	18	17	18	18	15	15	15	15	14	18	11	11
15	14	22	22	21	14	12	14	14	18	20	20	17	16	21	14	6
Total	388	357	436	417	362	294	331	327	406	408	402	405	396	447	389	303

[a] Legend:

Symbol	Parameter	Symbol	Parameter
Y_1	Total coliform	Y_9	Total solids
Y_2	Fecal coliform	Y_{10}	Dissolved solids
Y_3	Fecal streptococcus	Y_{11}	Volatile dissolved solids
Y_4	BOD	Y_{12}	Suspended solids
Y_5	COD	Y_{13}	Volatile suspended solids
Y_6	TOC	Y_{14}	pH
Y_7	Organic Kjeldahl nitrogen	Y_{15}	Chloride
Y_8	Soluble orthophosphate	Y_{16}	Specific conductance

TABLE 23

NUMBER OF SAMPLES COLLECTED FROM EACH TEST AREA BY EVENT NUMBER

Event No.	Date	Test Area No.															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1	Sept. 23			6				6									12
2	Oct. 5	6						6									12
3	Oct. 9	6	3	4				6						3			22
4	Oct. 16	7	7	7				2						6			29
5	Nov. 2				5			3						2		7	17
6	Nov. 10				3	7					1					1	12
7	Nov. 15				4	7					7				7	7	31
8	Nov. 26				7	7											14
9	Dec. 18				5	6					2						13
10	Dec. 27				3	8					5				8	2	26
11	Jan. 15				6								7				13
12	Jan. 29						1		1	1		4	4				11
*[a]	Feb. 11	1		1	1	1	1					1	1	1			8
13	Feb. 20	3	3	4	1		1	4	1	1		1	3				22
*	Mar. 12	1	1	1	1	1	1	1			1	1	1	1			11
14	Mar. 23	2	3	2			2	3	1	1		3	1				18
15	Apr. 13			3	3			3						3			12
16	Apr. 16			2		3		3			3			3			14
17	Apr. 26													6			6
18	May 6	2	2	2	2		2	2	2	2		3	2				21
19	May 15	1	1	1	1		1	1	2	1		4	2				15
20	May 24			3													3
21	June 8	1		2	1												5
*	June 11	1		1	1		1	1	1			1	1	1			9
22	June 12	1			1		1	1	1	1	1	1	1				9
23	June 13			3		3		1									6
24	June 14													3	1	1	5
25	June 17	1	1			1	3	1	3	3	2	3	3				21
26	June 23	1		3			1	4	1	1		1	1				13
27	June 24	1	1	1		1					3			1	1	1	10
*	July 30	1		1	1		1	1	1		1	1	1				9
28	July 31	2	2	3	1	1	1		1	1	3	1	1	1		1	19
29	Aug. 14	2	1	2		4		3		2	3	3	1				21
30	Aug. 15		2		2	2	2		2	2	3	2	2	2	1	2	24

[a] Baseline samples are indicated by asterisks.

SECTION 8

RESULTS OF STORM WATER POLLUTION ANALYSIS

This section presents the results of the analytical observations of the various pollution parameters measured throughout the testing period. These results are presented in tabular form in five pollution classifications: Bacterial, Organic, Nutrient, Solids, and Other Parameters. The data are tabulated as average values of the separate precipitation events and not as averages of the individual samples collected. This was done to more effectively compare the individual event characteristics. Since continuous sampling at each site for each event was not practicable, the averaging of the sequential samples for the sites which were continuously monitored was felt to yield more representative comparisons between these sites and those where only grab samples were obtained. Reference is made to Table 23 in Section 6 for the number of samples collected for each event from each test area.

Chemical and bacterial characteristics found in other studies of urban storm water runoff are shown in Tables 24 and 25. These values may be compared with the pollution levels found in this project.

Bacterial

The three bacteriological parameters measured on this project were total coliform, fecal coliform, and fecal streptococcus. All samples were examined by the membrane filter (MF) technique.

Table 26 shows the results of a cumulative frequency distribution of the three bacteriological parameters. This distribution was derived from data from all fifteen test areas.

These values may be compared with data from urban stormwater runoff as reported in the Cincinnati study (1). The frequency distribution reported in the Cincinnati investigation is shown in Table 27. It should be noted that the 90% and 50% values for the cumulative frequency distributions found in this study are in all cases lower than the corresponding values from the Cincinnati report.

The geometric means of the three bacteriological parameters measured from each test area are shown in Table 28. Table 29 presents the mean ratios and standard deviations of the bacterial pollution parameters. The overall geometric means of the bacterial parameters from all fifteen

TABLE 24

CHEMICAL CHARACTERISTICS OF URBAN STORM WATER RUNOFF
(OTHER STUDIES)

Location and Date	Parameter (mg/l)								
	BOD		COD		Organic N		Soluble PO_4		SS
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Mean
Cincinnati 7/62-9/63	2-84	19	20-610	99	0.2-4.8	1.7	0.07-4.3	0.8	210
Detroit 1949	96-234	147							
Ann Arbor 1965	Max. 62	28			Max. 4.0	1.0	Max. 3.4	0.8	2,080
Oxney, Eng. 1954	Max. 100								
Moscow, USSR 1936	186-285								
Leningrad, USSR 1948-50		36							
Seattle 1959-1960		10			Max. 9.0				
Stockholm 1945-1948	Max. 80	17	Max. 3,100	188					
Pretoria, S. Africa									
Residential		30		29		5.4			
Business		34		28		3.5			

TABLE 25

BACTERIAL CHARACTERISTICS OF URBAN STORM WATER RUNOFF
(OTHER STUDIES)

Location and Date	Source	Bacteria (Number/100 ml) Total Coliform	Fecal Coliform	Fecal Streptococcus	Remarks
Cincinnati 7/62-4/63		58,000	10,900	20,500	(Median values)
Cincinnati 1/62-1/64	Street Gutters				
	Spring	1,400	230	3,100	(Median values)
	Summer	90,000	6,400	150,000	
	Autumn	290,000	47,000	140,000	
	Winter	1,600	50	2,200	
	Business District				
	Spring	22,000	2,500	13,000	(Median values)
	Summer	172,000	13,000	51,000	
	Autumn	190,000	40,000	56,000	
	Winter	46,000	4,300	28,000	
Seattle 1959-1960		16,000			MPN/100 ml
Pretoria S. Africa	Residential	240,000			
	Business	230,000			MPN/100 ml

TABLE 26

BACTERIAL DENSITIES IN URBAN STORM WATER SAMPLES FROM 15 TEST AREAS, TULSA, OKLAHOMA

Bacterial Parameter	No. of Samples	Numbers Exceeded in Designated Percent of Samples (number/100 ml) 90%	50%	10%
Total Coliform	389	2,100	57,000	1,140,000
Fecal Coliform	358	2	30	30,000
Fecal Streptococcus	304	2	5,000	167,000

TABLE 27

BACTERIAL DENSITIES IN URBAN STORM WATER SAMPLES FROM CINCINNATI STUDY

Bacterial Parameter	Numbers Exceeded in Designated Percent of Samples (number/100 ml) 90%	50%	10%
Total Coliform	2,900	58,000	460,000
Fecal Coliform	500	10,900	76,000
Fecal Streptococcus	4,900	20,500	110,000

TABLE 28

GEOMETRIC MEANS FOR BACTERIAL DENSITY (THOUSANDS/100 ml) IN URBAN STORM WATER FROM 15 TEST AREAS IN TULSA, OKLAHOMA[a] DATES: SEPTEMBER 1968 TO SEPTEMBER 1969

Test Area No.	Total Coliform				Fecal Coliform				Fecal Streptococcus			
	No. of Events	Min.	Geometric Mean	Max.	No. of Events	Min.	Geometric Mean	Max.	No. of Events	Min.	Geometric Mean	Max.
1	14	0.0	71	2,000	11	0.00	0.94	70	13	0.00	4.20	775
2	11	0.7	43	800	8	0.00	1.90	170	11	0.00	0.78	440
3	13	0.0	100	20,000	10	0.00	3.30	175	15	0.00	15.00	380
4	13	0.0	25	500,000	8	0.00	0.77	30	13	0.00	12.00	450
5	11	0.0	150	21,500	12	0.00	1.50	185	12	0.00	3.80	370
6	10	4.0	140	5,500	9	0.00	18.00	470	10	0.00	24.00	650
7	14	0.0	32	3,500	13	0.00	0.12	80	16	0.00	2.30	775
8	9	0.0	240	3,300	8	0.00	0.45	420	9	0.00	5.80	1,400
9	11	26.0	400	7,500	10	0.00	0.29	265	11	0.00	7.60	1,100
10	11	2.0	130	3,800	11	0.00	0.30	45	10	0.00	30.00	840
11	11	14.0	370	5,800	10	0.00	0.62	290	11	0.00	6.80	3,450
12	12	0.0	56	2,500	11	0.00	0.01	20	12	0.00	0.70	550
13	6	0.0	28	1,700	9	0.00	0.18	110	9	0.00	5.70	430
14	4	0.0	5	1,425	5	0.00	0.37	95	5	0.00	21.00	100
15	6	20.0	220	1,450	8	0.00	0.35	135	8	0.00	14.00	280

[a] Geometric means were calculated using the arithmetic means of each event sampled.

TABLE 29

MEAN RATIOS AND STANDARD DEVIATIONS OF BACTERIAL POLLUTION PARAMETERS FROM 15 TEST AREAS, TULSA, OKLAHOMA

Test Area No.	Classification	F. Col. /T. Col.		F. Col. /F. Str.	
		Ratio	Std. Dev.	Ratio	Std. Dev.
1	Light Industrial	0.075	0.115	0.428	0.520
2	Commercial-Retail	0.165	0.272	0.228	0.349
3	Residential	0.093	0.210	0.507	0.806
4	Med. Ind. -Residential	0.005	0.021	0.237	0.684
5	Residential	0.054	0.168	0.213	0.377
6	Medium Industrial	0.104	0.166	0.683	1.126
7	Residential	0.035	0.132	0.376	1.020
8	Residential	0.145	0.213	0.785	1.444
9	Residential	0.117	0.260	0.893	2.411
10	Commercial (Office)	0.034	0.071	0.081	0.177
11	Residential-Com. Mix	0.035	0.083	0.246	0.455
12	Open Land-Runways	0.024	0.092	0.102	0.232
13	Residential	0.162	0.345	0.169	0.257
14	Recreation (Golf)	0.005	0.017	0.341	0.986
15	Residential	0.013	0.025	0.840	1.057

test areas were:

Bacterial Parameter	Geometric Mean
Total Coliform	87,000/100 ml
Fecal Coliform	470/100 ml
Fecal Streptococcus	6,000/100 ml

These values were considerably in excess of the State of Oklahoma water quality criteria for recreational areas for body contact sports:

> In all areas designed as recreational areas for body contact aquatic sports, including swimming and skiing, bacteria of the coliform group shall not exceed 1,000/100 ml as a monthly average[1] value (either MPN or MF count) during the recreational season; nor exceed this number in more than 20% of samples examined during any one month; nor exceed 2,400/100 ml (MPN or MF count) on any day except during periods of storm water runoff. Provided, however, that the fecal coliform shall not exceed a geometric mean of 200/100 ml, nor shall more than 10% of total samples during any 30-day period exceed 400/100 ml. (11)

In all 15 test areas, the geometric means for total coliform were far above the 1000/100 ml designated by the water quality criteria; this value was exceeded in more than 90% of all samples taken. It should be kept in mind, however, that the geometric means reported in this study are exclusively from periods of storm water runoff, and should not be interpreted on the same basis as values obtained on samples taken during other periods as well. In reference to fecal coliform, Test Areas 7, 12, and 13 exhibited geometric means falling within the 200/100 ml maximum set by the criteria. Although considerably more than 10% of the fecal coliform samples exceeded 400/100 ml, such samples were not in the majority.

For the fifteen test areas, the fecal coliform value was, on the average, 3% of the total coliform value. The average fecal coliform to fecal streptococcus ratio varied from a low of 0.081 (Test Area No. 10) to a high of 0.893 (Test Area No. 9).

These low ratios indicate the source of the bacterial pollution to be warm-blooded animals other than man (12). An initial suspicion at the start of the project was that Test Areas No. 13 would record a high fecal coliform to fecal streptococcus ratio, since this drainage basin was unsewered and utilized septic systems for liquid waste disposal. After checking with the authorities at the Tulsa City-County Health Department, it was learned that the septic systems in this area function properly, and very few complaints had been reported in regard to the "pooling" of septic systems.

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[1] Logarithmic average based on a minimum of five samples per 30 days.

Test Area No. 9 had the highest total coliform geometric mean (400,000/100 ml). The lowest total coliform geometric mean (5,000/100 ml) was recorded from Test Area No. 14, which is a country club golf course. This low geometric mean may be due to the small number of sample analyses from this drainage area. The one characteristic of this watershed which distinguishes it from the other test areas is that there are two small recreation ponds on the drainage channel; these ponds capture almost all of the runoff water. The only time that the drainage channel flows is after or during a precipitation event of high intensity or large amount. Such an event normally occurs during the spring of the year. Because of this characteristic, the samples actually collected were from the overflow of impounded water rather than actual runoff water.

No clear-cut relationships were found between the bacterial parameters and land use activities. Some correlation with the environmental conditions of the test areas, on the other hand, is evident as seen in Table 54 in section 10. It appears that the test areas with the worst environmental condition produce the greatest numbers of bacteria in storm runoff.

Organic

The three parameters measured on this project to determine the amount of organic pollution were 5-day, 20°C, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC). Table 30 summarizes the analytical results. These averages and ranges are based on the averages for each rainfall event sampled. Figure 16 illustrates the average values of all three parameters. Tables 31 and 32 present respectively the mean ratios of the organic pollution parameters and selected organic to solids ratios.

In general, all three organic parameters were moderate and not extremely high. The COD values appear to have the most significant variation between the test areas. The organic pollution parameter ratios (BOD/COD and TOC/COD) and certain individual observations indicate that some organic material of storm water runoff does not show up in the standard COD test. The organic material may, therefore, include straight-chain aliphatic components, aromatic hydrocarbons, and

TABLE 30

AVERAGE AND RANGE FOR BOD, COD, AND TOC IN URBAN STORM WATER RUNOFF FROM 15 TEST AREAS IN TULSA, OKLAHOMA
DATES: SEPTEMBER 1968 TO SEPTEMBER 1969

Test Area	BOD (mg/l)			COD (mg/l)			TOC (mg/l)		
No.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1	3	13	23	54	110	215	17	43	71
2	2	8	16	21	45	94	12	22	36
3	2	8	21	20	65	162	14	22	31
4	4	14	29	14	103	232	22	42	74
5	3	18	38	37	138	261	11	48	85
6	6	12	18	39	90	133	12	34	42
7	2	8	17	12	48	69	0	15	20
8	3	15	25	50	115	405	5	37	82
9	4	10	15	40	117	263	13	35	61
10	4	11	27	36	107	240	0	28	80
11	4	14	23	80	116	167	17	33	49
12	6	8	16	21	45	69	6	20	40
13	4	15	39	13	88	220	17	35	66
14	6	11	23	22	53	74	18	29	36
15	1	12	24	18	42	62	11	34	75

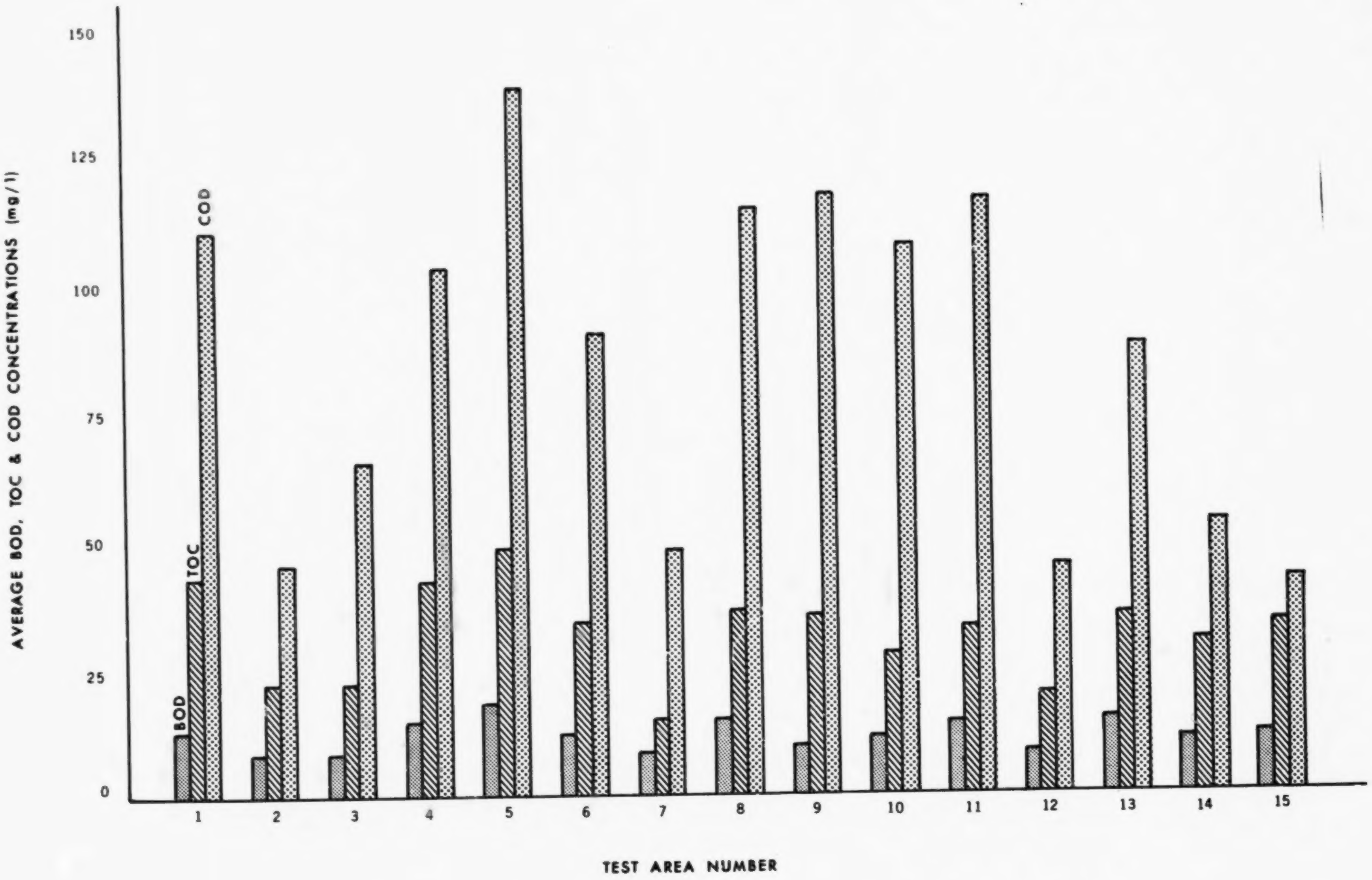

FIGURE 16 BAR GRAPH OF BOD, TOC & COD AVERAGE CONCENTRATIONS VS. TEST AREA NUMBER

TABLE 31

SELECTED MEAN RATIOS AND STANDARD DEVIATIONS OF ORGANIC POLLUTION PARAMETERS FROM 15 TEST AREAS TULSA, OKLAHOMA

Test Area No.	BOD/COD		BOD/TOC		TOC/COD	
	Ratio	Std. Dev.	Ratio	Std. Dev.	Ratio	Std. Dev.
1	0.129	0.062	0.289	0.164	0.447	0.158
2	0.220	0.248	0.415	0.416	0.636	0.400
3	0.134	0.069	0.304	0.138	0.465	0.283
4	0.176	0.192	0.368	0.162	0.445	0.331
5	0.163	0.106	0.357	0.152	0.396	0.223
6	0.149	0.095	0.434	0.239	0.445	0.237
7	0.150	0.099	0.379	0.205	0.289	0.158
8	0.162	0.083	0.462	0.180	0.379	0.140
9	0.120	0.039	0.403	0.257	0.373	0.136
10	0.105	0.043	0.396	0.217	0.349	0.327
11	0.119	0.051	0.375	0.165	0.334	0.088
12	0.208	0.071	0.529	0.301	0.495	0.228
13	0.127	0.068	0.389	0.238	0.525	0.514
14	0.263	0.230	0.391	0.246	0.591	0.215
15	0.342	0.213	0.577	0.331	0.847	0.591

TABLE 32

SELECTED MEAN RATIOS AND STANDARD DEVIATIONS OF ORGANIC AND SOLIDS POLLUTION PARAMETERS FROM 15 TEST AREAS, TULSA, OKLAHOMA

Test Area No.	COD/VDS		TOC/VDS		COD/DS		TOC/DS	
	Ratio	Std. Dev.	Ratio	Std. Dev.	Ratio	Std. Dev.	Ratio	Std. Dev.
1	0.885	0.700	0.463	0.286	0.653	0.528	0.274	0.165
2	0.911	0.553	0.662	0.433	0.448	0.198	0.280	0.141
3	1.024	0.738	0.489	0.363	0.488	0.397	0.176	0.066
4	1.992	2.249	0.757	0.416	0.502	0.342	0.193	0.115
5	4.938	8.476	1.962	2.967	1.602	1.341	0.603	0.608
6	2.221	2.516	0.541	0.321	0.699	0.396	0.227	0.104
7	1.192	1.278	0.494	0.613	0.521	0.408	0.198	0.148
8	1.154	0.344	0.431	0.195	0.692	0.542	0.238	0.124
9	1.268	0.596	0.412	0.211	0.734	0.328	0.222	0.105
10	2.450	2.959	0.892	0.787	1.086	1.255	0.467	0.706
11	2.512	2.287	0.927	1.120	0.764	0.490	0.215	0.122
12	1.201	0.816	0.634	0.442	0.509	0.301	0.249	0.159
13	1.858	1.532	0.699	0.518	0.817	0.591	0.294	0.193
14	1.031	0.547	0.600	0.336	0.330	0.207	0.155	0.046
15	0.892	0.479	0.850	0.626	0.574	0.197	0.488	0.319

pyridine. These components are not oxidized to any appreciable extent in the COD test.

The average BOD concentrations from the fifteen test areas ranged from a low of 8 mg/l (Test Areas No. 2, 3, 7, and 12) to a high of 18 mg/l (Test Area No. 5). Test Areas No. 5 and 13 recorded the highest maximum single observations of 38 mg/l and 39 mg/l, respectively. Both of these test areas are classified as residential areas with medium to heavy tree cover.

With the exception of Test Area No. 10, all of the high average values occurred from test areas with moderate to heavy tree cover. Also, all of these areas had one other common factor: the condition of drainage channels offered many opportunities for the leaves and grass trimmings to become trapped in depressions, thus allowing a chance for this vegetation to decompose. This condition could explain the higher average BOD values.

The fact the fifteen test areas did not show extreme variations tends to indicate that the possible relationship between BOD values and land use is not present.

It is interesting to note that all of these average concentrations are approximately 50% of that reported for good secondary sewage treatment plants. Additional comparative data and calculations are presented in Section 9.

The BOD/COD ratio varied from 0.105 (Test Area No. 10) to 0.342 (Test Area No. 15). The average ratio from all fifteen sites was 0.171. The high ratio from Test Area No. 15 may be due to the small number of events sampled. Also, Test Area No. 14 is not typical, since the samples collected were not from runoff, but from overflow water from the ponds on the drainage basin.

The average BOD/TOC ratio from the fifteen test areas was 0.405. The range of values was from 0.289 (Test Area No. 1) to 0.577 (Test Area No. 15).

In general, these ratios are not useful for characterization of the test areas. There is considerable variation between the test areas, and each drainage basin has a high standard deviation.

Table 32 presents several selected mean ratios of organic to solids pollution parameters. The only interesting findings in this group of ratios were the high calculated ratios from Test Area No. 5. No logical explanation can be found for such high values except that this test area is a fairly old residential neighborhood with steep slopes and a large amount of tree cover.

Examining the standard deviations of the ratios indicates that considerable variation is present from sample to sample, and no one site has a constant relationship.

Total organic carbon (TOC) was measured in conjunction with BOD and COD to further characterize the test areas. It was hoped that a constant relationship could be found between samples. The TOC/COD ratio varied from 0.289 (Test Area No. 7) to 0.847 (Test Area No. 15). The average of all fifteen test areas was 0.468.

The average values of the fifteen test areas show no positive groupings; the test areas with the three highest values are each classified differently.

In several instances the TOC concentrations were higher than the COD concentrations, indicating that the standard COD test did not detect some organic compounds. At present, this finding cannot be readily explained.

Nutrients

Organic Kjeldahl nitrogen and soluble orthophosphate were the nutrients measured in the study. The averages and ranges of values of these two components are given in Table 33. Figure 17 illustrates the average concentrations for both parameters. The means and standard deviations of the nitrogen to phosphorus ratios are shown in Table 34. The values that were obtained varied between land uses and sites.

With knowledge of the present land use and an examination of the data shown in Appendix M for some of the sites, several possibilities as to the sources of nutritional pollution can be advanced. Other sites exhibit such variation as to season, concentration, and so on, that logical deductions as to cause cannot be made unless more complete land use information is available.

The organic Kjeldahl nitrogen measured in the runoff could have been obtained from several sources. The entrainment of organic matter by surface flows, and the eluviation of decay products from organic matter are probably responsible for a large portion of the nitrogen load. Derivatives from commercial fertilizers are potential high pollution sources in the event that precipitation events occur at high intensities after these fertilizers have been applied on the land surface. Ammonia and

TABLE 33

AVERAGE AND RANGE FOR NUTRIENT CONCENTRATIONS IN STORM WATER RUNOFF FROM 15 TEST AREAS DATES: SEPTEMBER 1968 TO SEPTEMBER 1969

Test Area No.	Organic Kjeldahl Nitrogen (mg/l)			Total Soluble Orthophosphate (mg/l)		
	Min.	Avg.	Max.	Min.	Avg.	Max.
1	0.06	1.11	2.95	1.20	3.49	15.10
2	0.17	0.95	3.61	0.24	0.86	1.50
3	0.24	1.48	3.28	0.10	1.92	3.70
4	0.00	0.97	3.03	0.36	1.05	3.00
5	0.00	0.72	1.80	0.53	0.87	1.53
6	0.16	0.65	1.50	0.58	0.86	1.40
7	0.01	0.80	1.60	0.28	0.67	1.43
8	0.00	0.69	2.52	0.00	1.15	2.60
9	0.14	0.67	1.30	0.48	1.02	1.92
10	0.06	0.83	2.40	0.30	0.70	1.50
11	0.13	0.66	1.82	0.60	1.11	1.88
12	0.01	0.39	1.26	0.20	0.54	1.68
13	0.15	1.46	5.32	0.10	1.18	1.97
14	0.13	0.96	2.40	0.09	0.99	2.25
15	0.15	0.36	0.98	0.35	0.81	1.17

TABLE 34

MEAN AND STANDARD DEVIATION OF RATIO OF ORGANIC KJELDAHL NITROGEN TO SOLUBLE ORTHOPHOSPHATE

Test Area No.	N/PO_4	
	Ratio	Std. Dev.
1	1.929	1.455
2	4.080	3.013
3	2.676	1.606
4	4.008	3.813
5	2.950	2.995
6	2.193	1.502
7	4.425	3.491
8	1.867	1.670
9	2.201	1.813
10	3.191	2.436
11	2.446	2.833
12	4.210	5.435
13	5.800	5.175
14	2.086	0.696
15	2.591	4.513

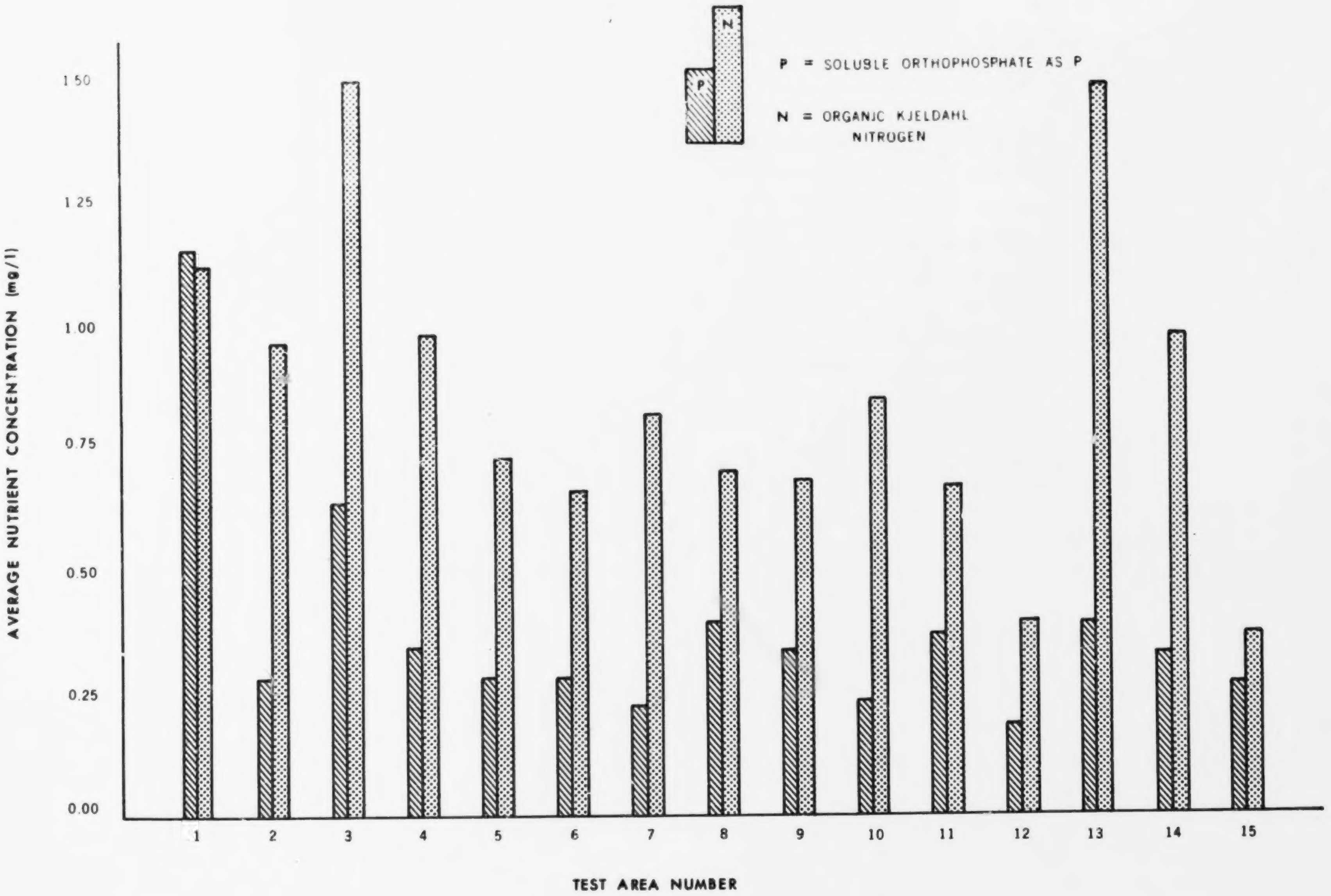

FIGURE 17 BAR GRAPH OF AVERAGE NUTRIENT CONCENTRATION VS TEST AREA NUMBER

organic nitrogen are also washed from the air at rates of 2 to 6 pounds per year (13).

A valid apportionment of the measured nutrients to these sources is not possible, and only inferences can be made. In the spring, Test Areas 2, 3, and 13 exhibit increased levels of organic nitrogen which can be attributed to fertilization of lawns within these high-income residential areas. Other sites have high values during the fall, winter, and spring which could be assigned to organic decay. A decrease in organic nitrogen is seen during the growing season due to the rapid assimilation of any free nitrogen by growing vegetation.

The flows from Site 7 were considered to be primarily from the impervious portion of the drainage area. Using the average value of the nitrogen as the multiplier, an estimate of the nitrogen load from the site was obtained by a procedure described in Section 9 of this report. When the estimated load was apportioned to the calculated imperviousness of the site, a value of 7.0 pounds per acre per year was obtained. Tabulation of the annual loads from the impervious portion of other test areas showed that Sites 2, 4, 5, 6, 8, 9, 10, and 11 exhibited annual values which fell within a range of 4.9 to 7.3 pounds per acre. These loads could be assigned to both washout from the air and to organic nitrogen sources deposited on the impervious portion of the watersheds.

Of the remaining sites, only Test Areas 3 and 13 are justifiable when the nitrogen loads are assigned just to the impermeable portion of the sites. The higher average nitrogen values of these two sites can be attributed to the apparent washout from heavy yard fertilizations in the spring. The high value for Test Area 14 can be attributed to the decay products of organic matter present within the channels and lakes of the drainage way during the two fall events that were sampled. Site 1 was in a state of flux with construction taking place at the site during much of the test period. Erosion took place at these construction sites, and the organic matter which was eroded probably contributed to the high average nitrogen value. Sites 12 and 15 were both flat and had low average values. Drainage from the paved parking aprons and runways in Test Area 12 runs into grassed channels, and ample opportunities exist for seepage and for assimilation of the entrained nitrogen by plants. Site 15 has old streets and curbings. Puddling along the curbing is commonplace, and drainage amounts from the area are low.

The varying amounts of orthophosphate found in the analysis of the study sites can likewise be assigned to various sources. The frequency of street sweepings; the amount, type, and location of organic material and its decay products; the application of commercial fertilizer; the season; the number of sampled events; and the drainage characteristics can either singularly or in combination influence the washout of orthophosphate from the test sites.

The presence of a concrete plant upstream from the sampling point was the prime cause of the high level of orthophosphate in Test Area 1. This plant affected these levels either through the eluviation of limestone containing soluble phosphates from the plant site or through the furnishing of highly basic calcium hydroxide solutions which stripped the phosphates from suspended clays in the storm runoff.

The prairie soils in this area are high in soluble phosphates, and the breakup of land at the construction sites enabled soils to be eroded. Site 4 contained some concrete plants also, but the resultant influence of high total solids and high pH on the level of orthophosphate was not as striking as that exhibited by Test Area 1.

Sites 3 and 13 exhibited high average orthophosphate levels which resulted from the heavy lawn fertilizations in the spring. The high maximum levels which are shown for 8 and 14 are caused by organic decay products. Test Area 12 had low orthophosphate levels due to low runoff volumes and the lack of decidous vegetation.

If the amounts of orthophosphate are apportioned just to the impermeable portions of the site as was done previously for organic Kjeldahl nitrogen, Test Area 10, located in the central business district, has 4.34 pounds, the lowest annual amount per impermeable acre. This value appears reasonable in that most of the runoff-producing portion of the streets is swept each night, and there is relatively little organic matter from vegetal sources in the drainage ways of the area. Site 2 was also low in pounds per impermeable area, but since it contained a higher percentage of residential area with its characteristic vegetation, the yield was greater than from Site 1. Site 7 also exhibited a low yield of orthophosphate per impermeable acre. This was thought to result from the low percentage of covered storm sewers and from the low contribution of surface flow from the pervious areas. The remaining areas had larger yields of orthophosphate per impervious area; this finding was attributed to the larger amounts of tree cover in these older developed areas.

Solids

The five solids constituents measured on this project were total solids (TS), suspended solids (SS), volatile suspended solids (VSS), dissolved solids (DS), and volatile dissolved solids (VDS). The arithmetic averages of these constituents are summarized in Table 35. These averages are based on the average of each event sampled from the fifteen areas. Figure 18 illustrates the average values for total solids, suspended solids, and dissolved solids. Selected ratios were calculated to provide further insight into the character of urban runoff pollution from different types of land activity. These mean ratios and standard deviations are shown in Table 36.

Total solids is the sum of the suspended solids and dissolved solids fractions; it is closely related to the topography and soil conditions of the various test areas. It should be noted that, due to the sampling techniques, total solids is not a measure of all solids found in urban storm runoff. All solids would be the sum of total solids and the floating and large particles not picked up by the sampler used on this project. These "other solids" include such materials as tree limbs, leaves, paper, plastics, etc. Such materials are not only objectionable as to aesthetics, but indirectly add to the bacterial, organic, and nutrient storm water loads. For example, during late fall large amounts of leaves reach the storm drainage system and become trapped in depressions within the system. Between the rainfall that carries the leaves to the system and the next precipitation event, the leaves have time to decay and disintegrate, thus adding additional organic and nutrient contaminants to the runoff water.

The average values for the solids show considerable variation. The lowest average value for total solids (199 mg/l) was found from Test Area No. 12. Test Area No. 1 had the highest average value (2242 mg/l). The value for this site was eight to nine times greater than the average for the other test areas. This extremely high concentration can be explained by exposed open land. Shortly after the start of the project, construction began on a large apartment house complex. The land was stripped of its ground cover, cuts were made for streets, and water and sewer line trenches were dug. Construction continued throughout the project. Therefore, this test area is representative of a drainage basin that is under development.

The second highest average value (680 mg/l) for total solids was recorded from Test Area No. 3. This test area is a new fully developed middle-class subdivision. A large portion of the main drainage channel is open and unimproved, with unstable banks.

The percentage of suspended solids varied from a low of 38% (Test Area No. 12) to a high of 82% (Test Area No. 1). The remaining test areas had percentages from 40% to 60%. The suspended solids concentrations were ten to twenty times higher than the concentrations reported for Tulsa's sewage treatment plants. The low value from Test Area No. 12

TABLE 35

AVERAGE VALUES FOR SOLIDS
FROM 15 TEST AREAS IN TULSA, OKLAHOMA
DATES: SEPTEMBER 1968 TO SEPTEMBER 1969

Test Area No.	Classification	No. of Storms	No. of Samples	Average Solids (mg/l)				
					Suspended		Dissolved	
				Total	Total	Volatile	Total	Volatile
1	Light Industrial	14	36	2242	2052	296	190	111
2	Com. -Retail	10	23	275	169	48	106	70
3	Residential	16	48	680	280	53	400	317
4	Med. Ind. -Res.	15	46	616	340	83	276	87
5	Residential	13	50	271	136	54	135	76
6	Med. Industrial	10	15	346	195	55	151	66
7	Residential	18	60	413	84	28	328	124
8	Residential	8	13	382	240	96	141	75
9	Residential	11	16	417	260	70	157	98
10	Commercial-Office	11	34	431	300	61	132	71
11	Res. -Com. Mix	11	26	575	401	95	174	83
12	Open Land-Runways	11	27	199	89	24	110	59
13	Residential	10	30	469	332	85	137	73
14	Recreation (Golf)	5	18	592	445	206	147	53
15	Residential	8	22	273	183	122	89	56

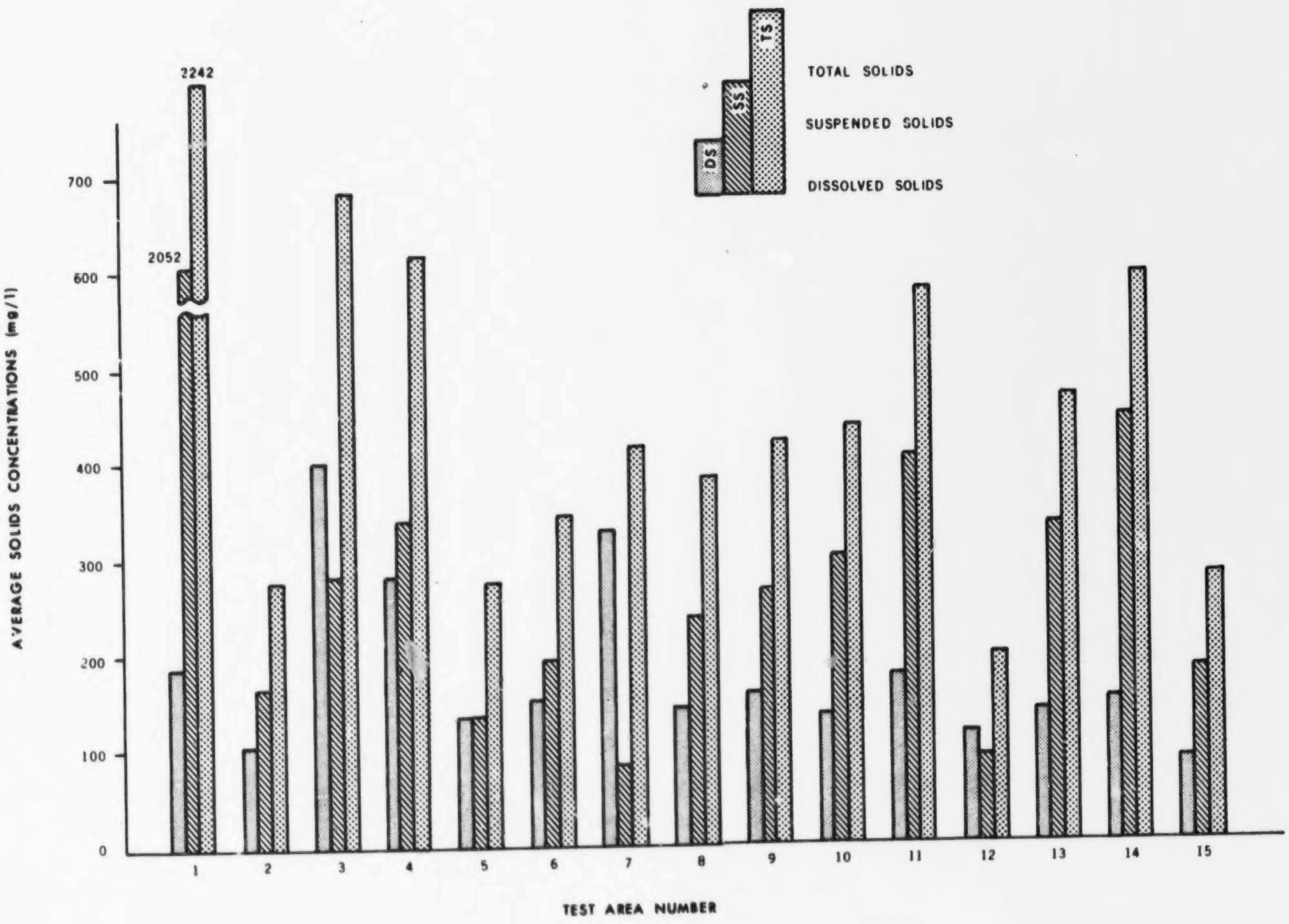

FIGURE 18 BAR GRAPH OF AVERAGE SOLIDS CONCENTRATIONS VS. TEST AREA NUMBERS

TABLE 36

MEAN RATIOS AND STANDARD DEVIATIONS OF VARIOUS SOLIDS COMPONENTS FROM 15 TEST AREAS, TULSA, OKLAHOMA

Test	SS/TS		VDS/DS		VSS/SS		DS/Cond.	
Area No.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1	0.819	0.208	0.521	0.154	0.228	0.172	1.688	0.888
2	0.505	0.234	0.538	0.254	0.399	0.292	1.450	0.902
3	0.528	0.221	0.508	0.233	0.315	0.188	1.420	0.725
4	0.483	0.194	0.326	0.156	0.272	0.212	1.653	0.912
5	0.454	0.166	0.518	0.216	0.467	0.248	1.578	1.000
6	0.514	0.197	0.423	0.130	0.393	0.230	1.381	0.475
7	0.404	0.242	0.514	0.212	0.495	0.298	1.251	0.546
8	0.524	0.157	0.484	0.118	0.314	0.164	1.508	0.415
9	0.533	0.221	0.620	0.129	0.311	0.200	1.696	0.646
10	0.530	0.273	0.514	0.224	0.326	0.212	1.469	0.513
11	0.639	0.169	0.433	0.243	0.302	0.169	1.583	0.593
12	0.379	0.224	0.499	0.209	0.412	0.324	1.678	1.001
13	0.612	0.261	0.498	0.195	0.287	0.184	1.591	0.685
14	0.594	0.188	0.382	0.252	0.348	0.346	1.191	0.349
15	0.427	0.245	0.594	0.220	0.526	0.231	2.543	1.342

is due to the fact that the runoff comes from airport runways and is channeled to the main drainage channel by well-kept drainage ditches along the runways. Also, the main sources of suspended solids in fully developed residential and commercial areas are the streets, in that they collect the dust, dirt, and clay droppings from automobiles. It is interesting to note that Test Area No. 12 also had one of the four highest volatile suspended solids to total suspended solids ratios.

Generally, the volatile suspended solids followed the same pattern as suspended solids, and formed 20-50 percent of the total suspended solids. It should be remembered that high values of volatile matter in storm water may not necessarily be decomposable organic material. The relatively low BOD values found on this project support this, as does the fact that clay will lose considerable weight on ignition.

The average total dissolved solids ranged from a low of 89 mg/l (Test Area No. 15) to a high of 400 mg/l (Test Area 3). The overall mean of the test areas was 178 mg/l. The volatile portion of the dissolved solids averaged 49% for the 15 test areas. The range of values was from 33% (Test Area No. 4) to 62% (Test Area No. 9).

Other Parameters

In addition to the bacterial, organic, nutrient, and solids pollution parameters measured on this project, the pH, chloride, and specific conductance were measured. Table 37 presents a summary of these results.

The average pH from the fifteen test areas varied from a high of 8.4 (Test Area No. 1) to a low of 6.8 (Test Area No. 15). All of these average values are within the water quality criteria assigned by the State of Oklahoma for the Arkansas River and Verdigris River. The criteria call for the pH to be between 6.5 and 8.5, and all values below 6.5 and above 8.5 must not be due to a waste discharge. The only observations of pH values that were higher than these limits were found from Test Area No. 1, which can be classified as a light industrial area. This test area recorded a maximum pH of 12.2 on October 16, 1968. The particular sample having this maximum pH value was the third in a series of seven 30-minute composite samples, and was collected approximately 5.4 hours after the rainfall event started. All the samples collected from this test area had consistently high pH values. The only sources of land contaminants that could be found within this drainage area were piles of cement, waste concrete, and other waste associated with a concrete batch plant operation. The batch plant is located on the bank of the unimproved

TABLE 37

AVERAGE VALUES FOR pH, Cl, AND SPECIFIC CONDUCTANCE
FROM 15 TEST AREAS IN TULSA, OKLAHOMA
DATES: SEPTEMBER 1968 TO SEPTEMBER 1969

Test Area No.	Classification	No. of Storms	No. of Samples	pH	Cl (mg/l)	Specific Conductance (micromhos/cm)
1	Light Industrial	14	36	8.4	11	120
2	Com. -Retail	10	23	7.3	10	78
3	Residential	16	48	7.3	13	110
4	Med. Ind. - Res.	15	46	7.5	10	154
5	Residential	13	50	7.1	8	89
6	Med. Industrial	10	15	7.5	9	105
7	Residential	18	60	7.4	46	220
8	Residential	8	13	7.4	10	101
9	Residential	11	16	7.4	5	100
10	Commercial-Office	11	34	7.4	10	104
11	Res.-Com. Mix	11	26	7.4	6	113
12	Open Land-Runways	11	27	7.2	4	64
13	Residential	10	30	7.3	15	105
14	Recreation (Golf)	5	18	7.1	13	114
15	Residential	8	22	6.8	2	36

open channel that drains the lower portion of this watershed.

The only test area that approached the lower limit of the State of Oklahoma's pH criteria was Test Area No. 15. The average pH value from this area was 6.8 and the lowest observed value was 6.4. The pH of the runoff from Site 15 can be attributed to contributions from several factors. The soils of the watershed were developed under forest-like conditions found along the terraces adjoining the Arkansas River bottoms before Tulsa developed. These conditions produced soils which were slightly acidic. This area is located in a fairly old residential neighborhood, and tree cover and other vegetation levels are approaching the levels once found in the primitive state. The decomposition of vegetation both on the ground surface and in covered storm sewers of the area contributes to lower pH values in the runoff water.

Average concentrations of chloride (Cl) from the fifteen test areas varied from 2 mg/l (Test Area No. 15) to 46 mg/l (Test Area No. 7). None of these values are excessive considering the average concentrations found in the two receiving streams in Urban Tulsa. The 50% value for chloride measured in the Arkansas River at Sand Springs, Oklahoma is 970 mg/l (11). The average concentration found in Bird Creek is 126 mg/l (14).

The only samples collected which were expected to show a possible increase in concentrations were those of February 20, 1969. These samples were collected from runoff originating from melting snow. The runoff samples were from the street source areas only, since the snow had not started melting on the roofs and yard areas. The results of these observations were very low (less than 15 mg/l).

Due to the scarcity of snow and ice events in this area, very limited amounts of salt are applied to the streets for snow and ice control. The main material used in Tulsa for snow and ice control is sand (see Appendix I). Due to such limited use, the natural concentrations found in the receiving streams, and the concentrations found from the fifteen test areas, the chloride (Cl) load reaching the receiving streams does not present a problem in the Tulsa area.

The average specific conductance from the fifteen test areas varied from a low of 36 micromhos/cm to a high of 220 micromhos/cm. The mean ratios of dissolved solids to specific conductance varied from 1.19 (Test Area No. 14) to 2.54 (Test Area No. 15).

The overall average of the means of the test areas was 1.579. None of the average values of the fifteen test areas deviated significantly from this mean, with the exception of Test Area No. 15. This finding tends to indicate that the dissolved substances in the runoff water from this test area are higher in organic compounds than in inorganic ions. Additional support for this conclusion is the relatively high volatile dissolved solids to total dissolved solids ratio of 0.594. This ratio, as compared with the other fifteen test areas, was second highest.

Phenols determinations were made on samples collected on June 17, 1969 from Test Areas No. 2, 5, 6, 10, and 11. The results of these determinations are shown below:

Test Area No.	µg/l
2	14
5	18
6	10
10	35
11	18

The above five values are within the range (1-30 µg/l) as reported in the Detroit-Ann Arbor study (3). It should be noted, however, that Test Area No. 10 recorded the highest concentration (35 µg/l). This test area is a downtown central business district having a high percentage of streets and heavy traffic volumes.

Since phenols are subject to rapid biochemical and chemical oxidation, they must be preserved and stored at cold temperatures if not analyzed within 4 hours after collection. Due to this requirement and to the sampling procedures used on this project, additional determinations were not made.

SECTION 9

STORM WATER POLLUTION ESTIMATES

In the preceding section, the data presented have been based on factual analytical observations. It should be noted that the pollution loadings calculated and presented in this section are estimates. These loading estimates (BOD, COD, organic Kjeldahl nitrogen, soluble orthophosphate, and total solids) are presented by month for each test area. Additional quality and quantity data are given for the two receiving streams (Arkansas River and Bird Creek) in the Tulsa urban area. Information concerning the pollution loadings from Tulsa's four treatment plants can be found in Appendix J.

Precipitation and Runoff

Storm water pollution is the end product of many processes which occur in a drainage basin. The linkage between these processes is runoff, which itself is the product of a complex interaction of factors brought about by precipitation events. Therefore, the precipitation-runoff regimen of an area must be investigated as a first step in determining storm water pollution problems. Table 38 lists some of the pertinent precipitation data for the Tulsa area.

The limited length of the study and the relatively small number of precipitation events available for sampling during the study period necessitated an analysis of precipitation events and patterns over a longer time span in order that meaningful surface runoff relationships could be developed. The five year period from 1964 to 1968 was used for this purpose. Tables L-1, L-2, and L-3 (Appendix L) and Figure 19 were developed from the hourly precipitation amounts recorded by the weather bureau at the Tulsa International Airport.

The precipitation regimen of the Tulsa area is portrayed in the information shown in these figures. The months with the most frequent events and the largest amounts of rainfall are April and May. From June through October, the major portion of the rainfall occurs in short, high intensity showers resulting from local convective storms. In the period from November to March, the convective activity lessens, and most of the rainfall events occur in conjunction with frontal storms. This type of rainfall is characterized by low intensity, uniformly distributed precipitation. The cumulative frequency distribution curve

TABLE 38

PRECIPITATION MEANS AND EXTREMES[a]

Month	Precipitation (in.)			
	Average Monthly	Maximum Monthly	Minimum Monthly	Maximum in 24 hours
J	1.68	6.65	T[b]	2.25
F	1.59	3.95	0.40	1.77
M	2.72	6.14	0.25	2.66
A	4.10	9.23	0.51	4.58
M	5.16	18.00	1.33	7.30
J	4.58	11.17	0.53	5.01
J	3.27	10.88	0.03	7.54
A	3.19	7.47	0.21	4.16
S	3.58	10.50	T	6.39
O	3.21	16.51	T	5.46
N	2.33	7.57	0.01	2.77
D	1.84	4.29	0.16	3.19

[a] Source: U. S. Department of Commerce Environmental Science Service Administration, Local Climatological Data, 1968 Annual Summary for Tulsa, Oklahoma. Asheville, N. C.: National Weather Records Center.

[b] T=Trace--An amount too small to measure.

shows that only about 8.5 percent of the storm events produce rainfall amounts greater than one inch. Under this precipitation regimen, runoff from natural areas should be low.

This assumption was checked through the computation of average monthly runoff values for the Bird Creek watershed above the USGS gage near Sperry, Oklahoma. More than ninety nine percent of the watershed area is in a natural state. The average monthly flows for the watershed are given in Table 39.

These figures reflect the information given in Appendix L describing the precipitation regimen. The months with higher event frequencies and with substantial percentages of the events in the higher amount intervals (see Table L-2) have larger runoff values than other months.

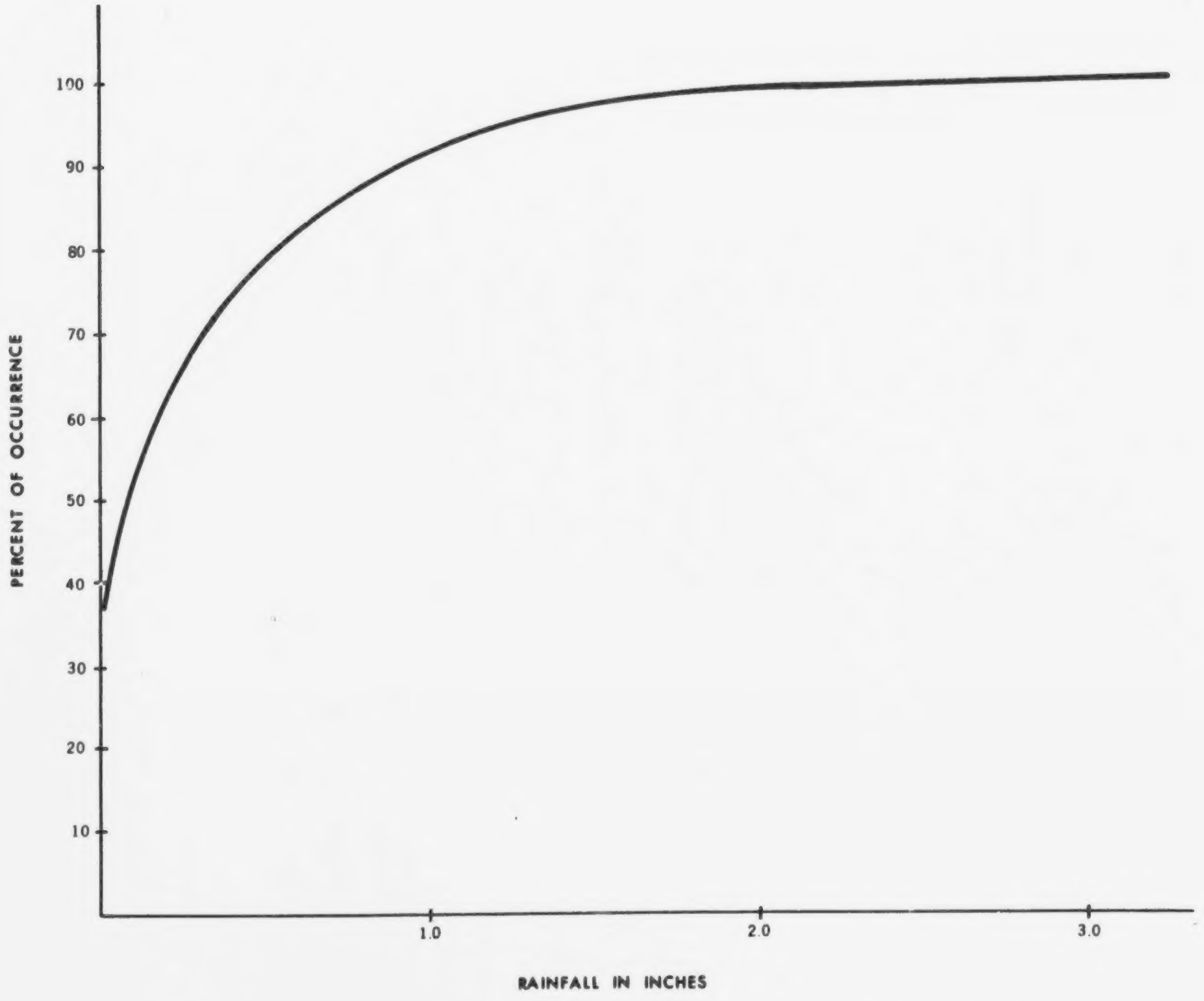

FIGURE 19 CUMULATIVE FREQUENCY DISTRIBUTION OF 465 RAINFALL EVENTS WHICH OCCURRED FROM 1-64 TO 12-68 AT TULSA INTERNATIONAL AIRPORT.

TABLE 39

CALCULATED AVERAGE RUNOFF FOR BIRD CREEK WATERSHED ABOVE THE SPERRY GAGE[a]

Month	Runoff in inches/acre
January	0.0870
February	0.0826
March	0.4757
April	0.9633
May	0.4415
June	0.2860
July	0.4177
August	0.0931
September	0.4221
October	0.0571
November	0.2110
December	0.1373
Total	3.6744

[a] Period 1964-1968

Due to the nearness of Tulsa to the gage at Sperry, it was deemed appropriate to transpose the runoff figures obtained from the gaged watershed for use in calculating the runoff volume from the pervious portions of the 15 test areas. Using these figures, the annual runoff from a natural site in the Tulsa area is seen to be approximately ten percent of the average annual rainfall for the period of record.

Studies on areas in a natural state have shown that these sites have places which contribute more frequently to runoff than others (15). Such places, unlike the paved portions of urban areas, vary their contributions to runoff in particular precipitation events. This variation is caused by the differences in soil moisture content, soil water storage capacity, infiltration capacity, and other factors for different regions in the watershed. Both between and during precipitation events, such variations cause fluctuations in the size of the watershed area contributing to runoff.

These circumstances cast doubt on the applicability of the procedure of assigning to each pervious acre an equal chance of contributing to runoff. At present, however, no techniques exist for a rapid analysis to determine the location, size, or sequential contribution of these part-time pervious tracts within a natural watershed. The monthly runoff volumes for the pervious areas within the test areas were thus estimated by multiplying the number of acres of pervious land within the site by the values given above for the Bird Creek basin.

The runoff volume from the sites is, therefore, composed of runoff from both naturally occurring and man-made impervious areas. The effects of these impervious areas on rates and volumes of runoff from pervious natural watersheds have been shown in other studies (16). The occurrence of flow events in the test areas at times when adjacent rain gages showed little or no rainfall for the same period, also indicated the dominating influence of man-made imperviousness on the runoff regimens of the urbanized study sites in Tulsa. In Figure 20, the measured amounts of runoff from Test Area 7 were plotted against the amount of precipitation obtained for the storm event. If the entire area was impermeable and there was no infiltration, evaporation, interception loss, or depression storage, then the points should fall along the line labelled $A_i/A=1$.

The size of the impervious area contributing to runoff within the site was then calculated. Since the roofs of most buildings in Test Area No. 7 are not guttered, and most residential driveways drain onto lawns or permeable areas rather than into storm sewers, the area of land covered by these two physical structures was multiplied by a runoff coefficient of 0. 5. This result was then summed with the area occupied by paved streets and by other large paved areas within the watershed. The resulting A_i/A ratio for the site was 0. 218. This ratio line is plotted in Figure 20 and represents the flow that would come from man-made impervious areas if there were no losses. It can be seen that the points lie fairly close to this line. It is of interest that, for the larger events, the points cluster below the line rather than above it. This indicates that the runoff samples from Test Area No. 7 were from areas of man-made imperviousness. Since the watershed outlet lay at a point midslope up a hill along an ephemeral drainage channel with the drainage area lying along the crest and upper slopes of the hill, the lack of runoff from the pervious areas is understandable.

The slope of the line of best fit through the data points was 0. 158. The difference between the line of best fit and the $A_i/A=0.218$ line was assumed to be a measure of the losses from the impermeable areas through evaporation, infiltration, and depression storage. The ratio of the lesser slope to the other was 0. 727. This value was then used as

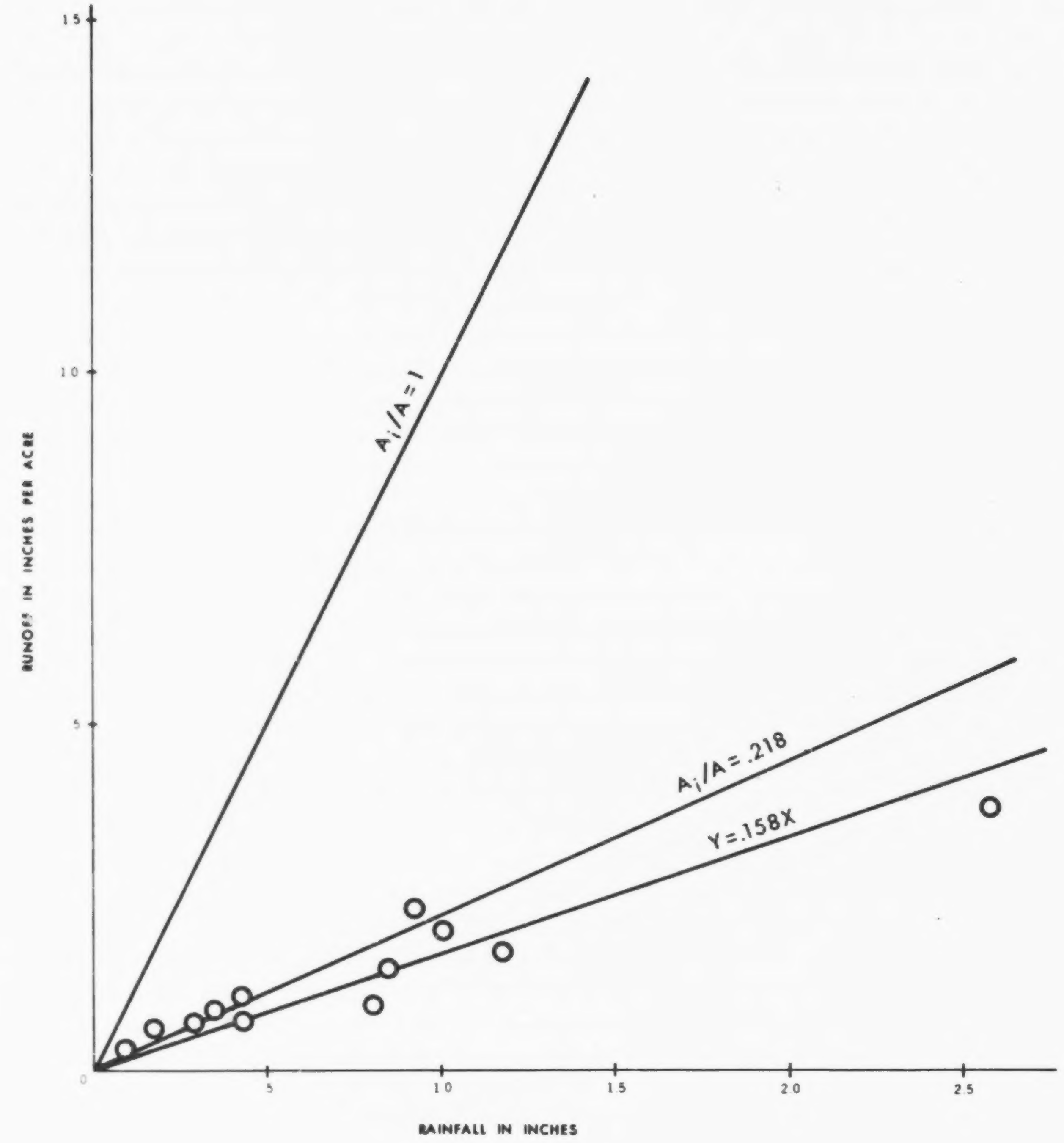

FIGURE 20 RAINFALL-RUNOFF RELATIONSHIPS FOR SITE NUMBER 7.

the runoff coefficient for all the impervious areas within the different study sites.

The amount of impervious area for the other sites was derived by the same procedure as that used for Test Area No. 7. The resulting figure was multiplied by 0.727 and by the monthly rainfall amount to arrive at an estimate of flow from the impervious area. This value was added to the estimated flow from the pervious portion of the watershed to obtain the total volume of the average monthly flow from each site. These estimates were used to calculate the information shown in Tables 40 through 44.

Estimates of Pollution Loads from the Study Sites

The necessity of traveling from site to site during any one rainfall event to collect samples and to inspect the operation of the sampling equipment precluded attempts to obtain continuous samples over the entire period of any single event. The capacity and rate of fill of the sequential sampling container was such that quality measurements for distinct periods of runoff could not be made once the sampled runoff began filling the overflow units. Measurements of flows at low stages during the short runoff periods were considered unreliable. No site was felt to have reliable data taken continuously over an entire runoff event for an actual load computation. Figures 21 and 22 show the distribution of BOD results at two sites for a storm which occurred in November 1968. Sampling ended at both test areas before the runoff ceased.

Precipitation at each site could be expected to vary due to differences in rainfall patterns over the city. For this reason, the records of precipitation for the Weather Bureau Station at the Tulsa International Airport were used as the base data for all test areas. The runoff from the test areas was calculated in relation to this precipitation pattern and was used to estimate the amounts of various pollutants washed annually from each site. This value was obtained by multiplying the average concentration of the parameter in question by the monthly flows. The monthly total loads per site are given in Tables 40 through 44. A more representative figure would have been obtained on the basis of the impervious area within each site. Further differentiation was not attempted, however, since the samples taken were not from source points within the sites. Table 45 gives the average daily loads per mile of street for each test area.

The breakdown and listing of pollution loads does allow a comparison to be made between different land uses. Some of these comparisons are

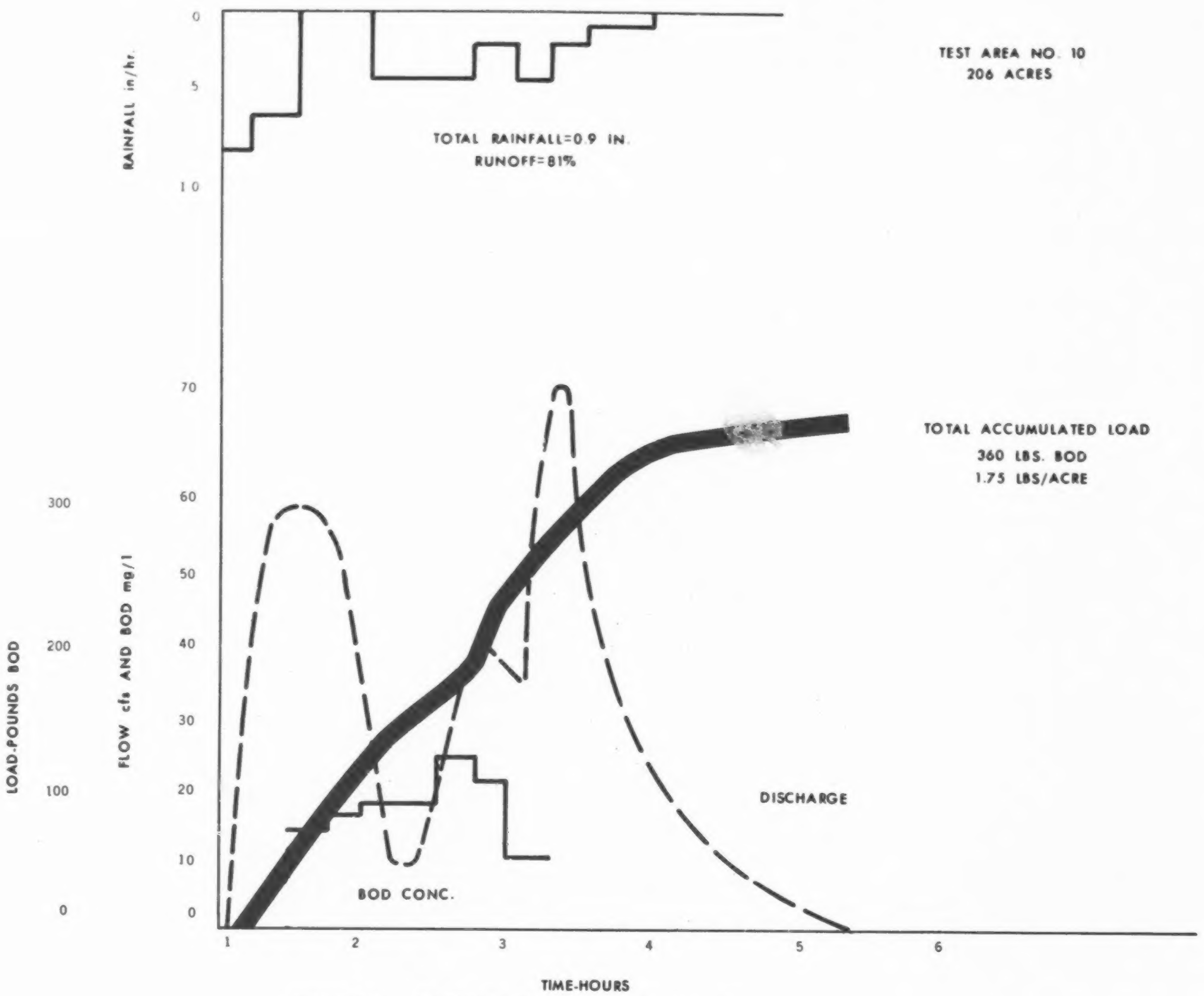

FIGURE 21 **RAINFALL OF NOVEMBER 15, 1968**

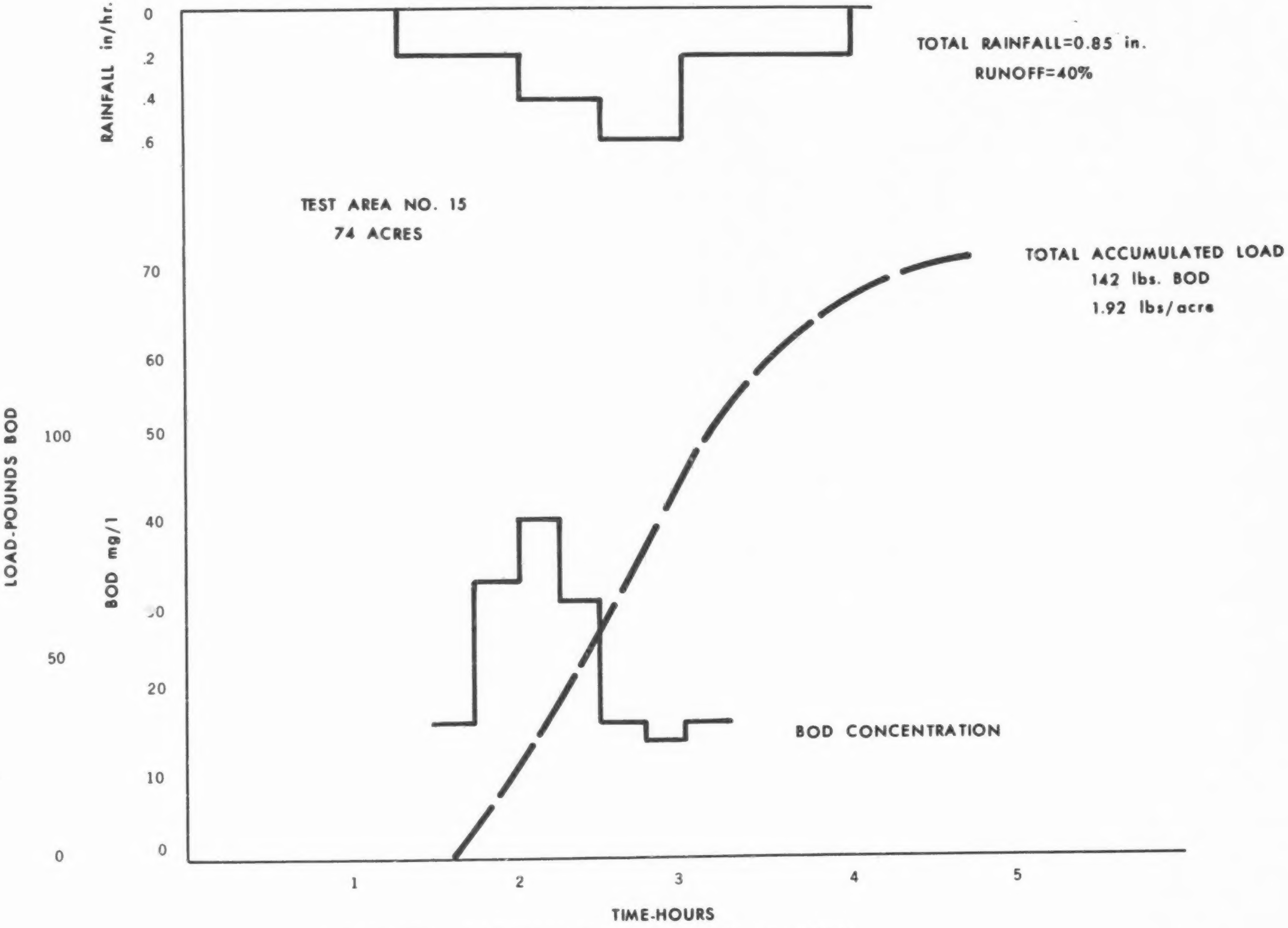

FIGURE 22 RAINFALL OF NOVEMBER 15, 1968

TABLE 40

AVERAGE MONTHLY BOD LOADS FROM THE FIFTEEN TEST AREAS

Test Area		Average BOD Load (lbs./acre)												
No.	Acres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	686	1.49	0.85	2.31	4.55	3.40	3.28	2.42	2.46	3.06	1.43	2.65	1.70	29.61
2	272	1.42	0.80	1.81	3.63	2.97	3.04	2.29	2.45	2.76	1.42	2.53	1.62	26.73
3	550	0.67	0.38	1.23	2.38	1.65	1.50	1.07	1.05	1.44	0.61	1.18	0.75	13.91
4	938	2.32	1.31	3.04	6.08	4.91	4.98	3.77	3.97	4.54	2.30	4.12	2.64	43.99
5	507	1.59	0.92	2.84	5.51	3.86	3.57	2.56	2.52	3.39	1.46	2.81	1.80	32.84
6	368	0.91	0.57	1.83	3.55	2.44	2.23	1.58	1.55	2.13	0.90	1.74	1.12	20.61
7	197	0.74	0.43	1.28	2.51	1.78	1.66	1.20	1.19	1.57	0.69	1.31	0.84	15.21
8	211	1.64	0.94	2.61	5.13	3.78	3.63	2.66	2.71	3.39	1.57	2.91	1.87	32.84
9	64	0.97	0.56	1.66	3.22	2.31	2.17	1.58	1.58	2.05	0.92	1.73	1.11	19.84
10	206	2.63	1.48	3.01	6.11	5.29	5.55	4.30	4.63	4.99	2.67	4.69	3.00	48.35
11	815	1.66	1.03	2.65	5.23	4.01	3.93	2.93	3.02	3.64	1.75	3.20	2.05	35.24
12	223	1.32	0.75	1.74	3.47	2.81	2.84	2.15	2.27	2.59	1.31	2.36	1.51	25.13
13	212	1.17	0.68	2.25	4.35	2.95	2.67	1.89	1.83	2.57	1.07	2.07	1.33	24.83
14	263	0.53	0.32	1.29	2.46	1.52	1.27	0.85	0.76	1.27	0.44	0.94	0.60	12.24
15	74	1.24	0.72	2.04	4.00	2.91	2.77	2.03	2.04	2.59	1.19	2.22	1.42	25.16

TABLE 41

AVERAGE MONTHLY COD LOADS FROM THE FIFTEEN TEST AREAS

Test Area		Average COD Load (lbs./acre)												
No.	Acres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	686	12.6	7.2	19.6	38.5	28.8	27.8	20.5	20.9	25.9	12.1	22.4	14.4	250.6
2	272	8.0	4.5	10.2	20.4	16.7	17.1	12.9	13.8	15.5	8.0	14.2	9.1	150.4
3	550	5.4	3.1	10.0	19.4	13.4	12.2	8.7	8.5	11.7	5.0	9.6	6.1	113.1
4	938	17.0	9.7	22.4	44.7	36.1	36.6	27.8	29.3	33.4	16.9	30.4	19.4	323.6
5	507	12.2	7.0	21.8	42.3	29.6	27.4	19.6	19.4	26.0	11.3	21.5	13.8	251.8
6	368	7.4	4.3	13.8	26.6	18.3	13.4	11.9	11.6	16.0	6.7	13.0	8.4	154.6
7	197	4.5	2.6	7.7	15.1	10.7	10.0	7.2	7.1	9.4	4.1	7.9	5.1	91.3
8	211	12.6	7.2	20.0	39.3	29.0	27.8	20.4	20.7	26.0	12.0	22.4	14.3	251.8
9	64	11.4	6.6	19.3	37.6	27.0	25.4	18.4	10.5	24.0	10.7	20.2	13.0	232.1
10	206	25.6	14.4	29.3	59.4	51.4	54.0	41.8	45.1	48.5	26.0	45.7	29.2	470.4
11	815	14.9	8.5	21.9	43.3	33.2	32.6	24.3	25.1	30.1	14.5	26.5	17.0	291.9
12	223	7.4	4.2	9.8	19.5	15.8	16.0	12.1	12.8	14.6	7.4	13.3	8.5	141.3
13	212	6.9	4.0	13.2	25.5	17.3	15.7	11.1	10.7	15.1	6.2	12.2	7.8	145.6
14	263	2.6	1.5	6.2	11.8	7.3	6.1	4.1	3.7	6.1	2.1	4.5	2.9	59.0
15	74	4.4	2.5	7.1	14.0	10.2	9.7	7.1	7.1	9.1	4.1	7.8	5.0	88.1

TABLE 42

AVERAGE MONTHLY ORGANIC KJELDAHL NITROGEN LOADS FROM THE FIFTEEN TEST AREAS

Test Area		Average Organic Kjeldahl Nitrogen Load (lbs./acre)												
No.	Acres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	686	0.127	0.073	0.198	0.389	0.290	0.280	0.207	0.211	0.261	0.122	0.226	0.145	2.529
2	272	0.168	0.095	0.215	0.573	0.353	0.360	0.272	0.291	0.328	0.168	0.300	0.192	3.316
3	550	0.123	0.071	0.228	0.441	0.304	0.278	0.209	0.224	0.253	0.129	0.218	0.140	2.618
4	938	0.160	0.091	0.211	0.421	0.340	0.345	0.261	0.276	0.314	0.159	0.286	0.183	3.048
5	507	0.063	0.037	0.114	0.221	0.154	0.143	0.102	0.101	0.136	0.059	0.112	0.072	1.314
6	368	0.053	0.031	0.099	0.192	0.132	0.121	0.086	0.084	0.115	0.049	0.094	0.060	1.116
7	197	0.074	0.043	0.129	0.251	0.178	0.166	0.120	0.119	0.157	0.069	0.131	0.084	1.521
8	211	0.076	0.043	0.120	0.236	0.174	0.167	0.123	0.124	0.156	0.072	0.134	0.086	1.511
9	64	0.065	0.038	0.110	0.216	0.155	0.146	0.106	0.106	0.140	0.061	0.116	0.074	1.332
10	206	0.198	0.112	0.227	0.461	0.399	0.419	0.324	0.350	0.376	0.202	0.354	0.226	3.649
11	815	0.085	0.048	0.125	0.247	0.189	0.185	0.138	0.143	0.172	0.082	0.151	0.097	1.661
12	223	0.064	0.037	0.085	0.169	0.137	0.139	0.105	0.111	0.126	0.064	0.115	0.074	1.225
13	212	0.114	0.066	0.219	0.423	0.288	0.260	0.184	0.178	0.250	0.104	0.202	0.130	2.416
14	263	0.046	0.027	0.113	0.215	0.133	0.111	0.074	0.066	0.111	0.039	0.081	0.053	1.069
15	74	0.037	0.021	0.061	0.120	0.087	0.083	0.061	0.061	0.078	0.036	0.066	0.043	0.755

TABLE 43

AVERAGE MONTHLY SOLUBLE ORTHOPHOSPHATE LOADS FROM THE FIFTEEN TEST AREAS

Test Area		Average Soluble Orthophosphate Load (lbs./acre)												
No.	Acres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	686	0.400	0.229	0.622	1.223	0.912	0.881	0.649	0.663	0.821	0.384	0.711	0.456	7.950
2	272	0.152	0.086	0.195	0.390	0.320	0.326	0.246	0.263	0.297	0.152	0.272	0.174	2.873
3	550	0.160	0.092	0.295	0.572	0.395	0.361	0.257	0.252	0.345	0.146	0.282	0.181	3.340
4	938	0.174	0.098	0.228	0.456	0.368	0.373	0.283	0.298	0.340	0.172	0.309	0.198	3.299
5	507	0.077	0.044	0.137	0.267	0.187	0.172	0.124	0.122	0.164	0.071	0.135	0.087	1.587
6	368	0.070	0.041	0.131	0.255	0.175	0.159	0.113	0.111	0.153	0.064	0.124	0.080	1.477
7	197	0.062	0.036	0.108	0.210	0.149	0.139	0.100	0.100	0.132	0.058	0.110	0.071	1.274
8	211	0.126	0.072	0.200	0.393	0.290	0.278	0.204	0.207	0.260	0.120	0.224	0.143	2.518
9	64	0.099	0.057	0.168	0.330	0.236	0.222	0.161	0.161	0.209	0.093	0.176	0.113	2.025
10	206	0.167	0.094	0.192	0.389	0.336	0.353	0.273	0.295	0.317	0.170	0.299	0.191	3.077
11	815	0.107	0.061	0.166	0.327	0.244	0.236	0.174	0.177	0.220	0.103	0.190	0.122	2.128
12	223	0.089	0.051	0.117	0.234	0.189	0.192	0.145	0.153	0.175	0.089	0.159	0.102	1.696
13	212	0.092	0.053	0.177	0.342	0.232	0.210	0.149	0.144	0.202	0.084	0.163	0.105	1.953
14	263	0.048	0.028	0.116	0.221	0.137	0.115	0.076	0.068	0.114	0.040	0.084	0.054	1.103
15	74	0.084	0.048	0.138	0.270	0.197	0.187	0.137	0.138	0.175	0.080	0.150	0.096	1.699

TABLE 44

AVERAGE MONTHLY TOTAL SOLIDS LOADS FROM THE FIFTEEN TEST AREAS

Test Area		Average Total Solids Load (lbs./acre)												
No.	Acres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	686	257	147	399	786	586	566	417	426	527	247	457	293	5107
2	272	49	28	62	125	102	104	79	84	95	49	87	56	918
3	550	57	33	105	203	140	128	91	89	122	52	100	64	1183
4	938	102	58	134	267	216	218	166	175	200	101	182	116	1936
5	507	30	14	43	83	58	53	37	38	51	22	36	27	494
6	368	28	16	53	102	70	64	46	45	61	26	50	32	594
7	197	38	22	67	130	92	86	62	61	81	36	68	43	785
8	211	42	24	67	130	96	92	68	69	86	40	74	48	836
9	64	41	23	69	134	96	91	66	66	85	38	72	46	827
10	206	103	58	118	240	207	218	168	182	195	105	184	118	1895
11	815	74	42	109	215	165	161	120	124	149	72	132	84	1447
12	223	33	19	43	86	70	71	54	57	64	33	59	38	625
13	212	37	21	70	136	92	83	59	57	80	33	65	42	776
14	263	29	17	70	132	82	68	46	41	68	24	50	32	659
15	74	28	16	46	91	66	63	46	46	59	27	50	32	572

TABLE 45

AVERAGE DAILY LOADS PER MILE OF STREET FROM THE 15 TEST AREAS

Test Area No.	Total Acres	Total Street Miles[a]	Total Street Acres	Average Load (lbs./day/mile of street) BOD	COD	T. Solids	Organic Kjeldahl Nitrogen	Soluble Orthophosphate
1	686	11.46	101	4.85	41.1	838	0.41	1.30
2	272	7.41	56	2.54	15.1	92	0.32	0.29
3	550	14.87	105	1.41	11.5	120	0.26	0.34
4	938	28.40	214	3.98	29.3	175	0.28	0.30
5	507	16.32	100	2.80	21.4	43	0.11	0.13
6	368	12.24	85	1.70	12.7	49	0.09	0.13
7	197	6.84	47	1.20	7.2	63	0.12	0.10
8	211	6.97	60	2.72	20.9	69	0.12	0.21
9	64	3.11	24	1.12	13.1	47	0.07	0.11
10	206	12.99	104	2.10	20.4	82	0.16	0.13
11	815	49.05	340	1.60	13.3	66	0.08	0.15
12	223	3.39[b]	103[b]	4.53	25.5	113	0.22	0.30
13	212	5.58	42	2.58	15.2	81	0.25	0.20
14	263	2.07	20	4.26	20.5	23	0.37	0.38
15	74	2.06	16	2.47	8.7	56	0.07	0.17
Mean	372	12.18	94	2.66	18.4	128	0.20	0.28

[a] Adjusted value based on width of streets and easements.

[b] Miles and acres of airport runways.

shown in Section 10.

Computation of Estimated Average Daily Storm Water Pollution Loads to Area Receiving Streams

An estimate of the average daily storm water pollution load can be obtained by multiplying the reported 1675 miles of streets in Tulsa (1100 miles paved) by the arithmetic mean of the 15 test areas shown in Table 45. This approach is plausible since the average load per mile of street per test area is based on the expected precipitation (based on 5-year record) and the average of the pollution parameter concentrations. Since the impervious areas (primarily streets) are the important source areas for storm water runoff pollution, it is also logical to relate the pollution loads to the length of streets. This methodology is intended only as a first-order, rapid estimating procedure rather than a complete analysis. The results using this procedure are shown in Table 46 along with comparisons utilizing data available from Tulsa's sewage treatment plants. In Table 47 the estimated average daily load is compared with the estimated average daily values for April--the month with the highest runoff value.

Considering the estimates presented in Tables 46 and 47, it is reasonable to speculate that with the continued urbanization of the Tulsa area in conjunction with the demands for increased efficiencies in waste treatment facilities, storm water runoff in the Tulsa area may well become the prime source of stream pollution within the next decade.

Of greater importance are not the estimated average daily loads, but the "shock" loads resulting from urban storm water runoff. There are, for example, an average of 52 rainfall events over 0.1 inch in Tulsa each year (See Table L-2 in Appendix L). If each event produced the same amount of pollution and occurred periodically at the end of equal increments of time, then approximately every 7 days a BOD load of 31,185 pounds (7 x 4,455) would be introduced into the area receiving streams in addition to the daily load of 10,370 pounds imposed by Tulsa's treatment facilities.

Such a storm water pollution load would reach the receiving stream in less than 24 hours. This consideration points out the fact that any treatment facility being utilized for storm water pollution alone would be in operation approximately 52 days per year. The average hydraulic load imposed on the storm water treatment facilities in the Tulsa area during or after the storm event would be approximately 310 million gallons. Since the average BOD concentrations are low, treatment

TABLE 46

ESTIMATED DAILY LOAD OF POLLUTANTS ENTERING THE AREA RECEIVING STREAMS

Parameter	Average Daily Storm Water Pollution Load in pounds	1968 Average Daily Load from Sewage Treatment Facilities[a] in pounds	Total Load	Percentage Contribution of Storm Water to Total Load
BOD	4,455	19,370	23,825	20
COD	30,803	67,180	97,983	31
Suspended Solids	107,200[b]	18,400	125,600	85
Organic Kjeldahl Nitrogen	355	760	1,115	31
Soluble Orthophosphate	469	11,020	11,489	4

[a] From Appendix J.

[b] Storm water suspended solids was estimated to be 50 percent of total solids.

TABLE 47

COMPARISON OF AVERAGE POLLUTION LOADS AND LOADS FOR APRIL

Parameter	Average Daily Load in pounds		Ratio of April to Annual
	Annual Basis	April Basis	
BOD	4,455	7,219	1.62
COD	30,803	54,760	1.78
Suspended Solids[a]	107,200	199,360	1.86
Organic Kjeldahl Nitrogen	355	529	1.49
Soluble Orthophosphate	469	749	1.50

[a] Storm water suspended solids was estimated to be 50 percent of total solids.

practices may not be feasible.

Storm Flow Amounts from Urban Tulsa

Estimates of the storm flows to Bird Creek and the Arkansas River, the major receiving streams in the metropolitan area, were obtained by the following procedure. The total number of acres classified under each category of land use in the land activity file of the TMAPC was determined for the two watersheds. These figures were multiplied by 0.25 to obtain an estimate of the impervious area within each drainage basin. The value of 0.25 appears reasonable since no actual figures for the areas of paved streets, driveways, parking lots, and roofs are maintained in the land use file. For example, if a standard four lane undivided highway with curbing (52 ft.) is constructed around a section of 640 acres, the highway by itself would "waterproof" approximately 3 percent of the section.

Using the figures of impervious acreage obtained above, the average monthly runoffs from the pervious and impervious sections of Tulsa in the Arkansas River and Bird Creek watersheds were obtained by the procedure described in the precipitation and runoff section of this report. These results are shown in Tables 48 and 49.

The dilution ratios given for the average monthly flows in the tables referred to above become meaningless when examined in conjunction with flow duration analysis as shown in Table 50. Only 33 percent of the time are the flows of Bird Creek greater than the estimated daily sewage flow in 1970. The estimated sewage flow in 1990 will be 58 mgd, and the Bird Creek watershed will produce flows greater than the sewage volume only 24 percent of the time. The construction of reservoirs in the upper Bird watershed and the resulting regulation of flow will decrease the number of days in which sewage flows will exceed the daily discharge from the drainage basin. With complete regulation of flows in the upper watershed and with no evaporation or seepage losses from the reservoirs, 282 mgd would be available for dilution of the sewage effluent. Realistically this will not be possible, however, and the amount actually available for dilution will be much less.

It can be expected that increases in urbanization of the watershed will continue to multiply the amounts of flow generated in storm runoff events. With more complete development, shock loads of pollution will be added in larger amounts and with greater frequency to the lower reaches of Bird Creek. When the costs for alternatives to prevent or treat storm

TABLE 48

SOURCES OF FLOW CONTRIBUTION WITHIN THE BIRD CREEK WATERSHED (DAILY AVERAGE)

Month	(1) Average Daily Volume From 1045 Square Miles of Natural Watershed[a] (mgd)	(2) Sewage Flow From Metropolitan Area to Bird Creek at 1970 Rate[b] (mgd)	(3) Estimated Storm Water Volume From 92 Square Miles of Urban Land (mgd)	Dilution Ratio (1)/[(2) + (3)]
Jan.	87	34	30	1.4
Feb.	54	34	19	1.0
Mar.	280	34	45	3.5
April	503	34	93	4.6
May	259	34	68	2.5
June	173	34	68	1.7
July	245	34	49	3.0
Aug.	54	34	50	0.6
Sept.	255	34	63	2.6
Oct.	33	34	29	0.5
Nov.	128	34	55	1.4
Dec.	80	34	34	1.2

[a] Based on years 1964-1968.

[b] The estimated 1970 sewage rate for the Tulsa metropolitan area is 59.9 mgd. This flow was apportioned to the percentage of the total urban area in the Bird Creek basin.

TABLE 49

AVERAGE DAILY VOLUMES COMPARING ARKANSAS RIVER FLOW AT TULSA WITH THE SEWAGE EFFLUENT AT THE SOUTH SIDE PLANT AND WITH STORM WATER RUNOFF FROM METROPOLITAN TULSA

Month	(1) Average Daily Flow of Arkansas River at Tulsa[a] (mgd)	(2) Sewage Flow From South Side Plant at 1970 Rate[b] (mgd)	(3) Storm Water Flow 67 Square Miles of Urban Area (mgd)	Dilution Ratio (1)/[(2) + (3)]
Jan.	1249	26	15	20.5
Feb.	960	26	10	26.7
Mar.	1455	26	27	27.5
April	2512	26	55	31.0
May	2934	26	37	45.8
June	5550	26	35	91.0
July	4265	26	24	85.3
Aug.	2473	26	23	50.5
Sept.	4454	26	33	75.5
Oct.	1944	26	14	48.6
Nov.	3411	26	27	64.4
Dec.	1805	26	17	42.0

[a] Based on years 1964-1968.

[b] The estimated 1970 sewage rate for the Tulsa metropolitan area is 59. 9 mgd. The flow was apportioned to the total urban area in the Arkansas River basin.

TABLE 50

COMPARISON OF SEWAGE FLOW WITH TOTAL FLOW FOR BIRD CREEK AND THE ARKANSAS RIVER[a]

Percent of Time Discharge is Equalled or Exceeded	Daily Volume of Bird Creek Near Sperry[b] in Million Gallons	Daily Volume of Arkansas River at Tulsa in Million Gallons
5	509.0	8,476
10	196.0	5,379
20	74.0	2,804
30	41.0	1,858
40	23.0	1,490
50	13.0	1,255
60	6.2	951
70	2.8	766
80	1.2	522
90	0.4	306
Daily Sewage Flows from Metropolitan Area to Appropriate Basin at 1970 Rate.	34	26

[a] Based on years 1964-1968.

[b] 79.5 percent of the Bird Creek watershed is located above the Sperry gage.

water pollution are considered, it may be necessary to continue using Bird Creek as the storm sewer for a large portion of Tulsa.

The storm water effluent to the Arkansas River from Tulsa causes no problems under present conditions. In the future, the continued urbanization of this area will cause increases in both storm and sewage flow to the river. Pollutional loads from sewage can be expected to decrease with the advent of new technology and with the enforcement of stricter quality standards. This factor should offset the increased loads brought down by storm runoff. The operation of Keystone Reservoir could be planned to minimize intolerable situations produced by the storm flows and their associated pollution. In the case that the River Lakes plan is implemented, the problems associated with storm water pollution will require immediate attention. For example, a 4 inch rainfall in a twenty-four hour period would produce from Test Area No. 10 alone a minimum volume of at least 17 MG of storm runoff containing an average of 8 tons of BOD and 75 tons of COD. Storms of this type have a two year return period for Tulsa and its environs.

Table 51 gives the average water quality of the two receiving streams in the Tulsa area. These values can be used as the base from which dilution concentrations can be calculated in storm runoff events.

When considered in the true context, the values of the pollution multipliers used in this section were based on a limited amount of information. The limitations emerge since the analysis was performed on a minute fraction of the flow volume taken over an infinitesimal portion of the time span in which the flow was occurring. Whether the samples were a representative mix of the multitudinous factors which contributed to the flow and pollution is unknown. It is speculation also as to whether the combined effects of these factors are reproduced with predictable certainty, or whether each event is unique in nature. At present, when compared with the ranges of the pollution parameters found in the effluents of the municipal treatment plants, the levels of pollution from storm water runoff found in the study samples are in themselves no cause for alarm.

The problem which arises is the magnitude of the total pollutional loads which issue from an urban area. The estimates of pollution given in this section are therefore presented as valid indicators of the pollutional loads which are generated annually on each of the study sites. The rapid development of a metropolitan area such as Tulsa, and the unceasing aggregations of the pollutional loads into the drainage ways of the area will continue the decline of a valuable portion of the regional

TABLE 51

RECEIVING STREAM WATER QUALTIY DATA[a]

Stream and Location	D. O. mg/l	BOD mg/l	COD mg/l	Organic Kjeldahl Nitrogen mg/l	Ortho-phosphate mg/l	Cl mg/l	pH
Arkansas at 51st St. Bridge	9.4	4	40	0.31	0.80	239	8.3
Bird Creek at Avant Oklahoma	7.5	4	17	0.38	0.23	41	7.7

[a] Source: U. S. Dept. of HEW, FWPCA, Preliminary Studies Arkansas River and Tributaries, Tulsa to Muskogee, Oklahoma, February, 1966.

environment. The degraded conditions which are emerging in conjunction with this type of pollution defy an economical solution with present technology.

SECTION 10

ANALYTICAL PROCEDURE FOR STORM WATER POLLUTION ASSESSMENT

Introduction

The methodology used in investigating and establishing the relationships of the pollution parameter concentrations to the various explanatory variables included the standard statistical techniques of correlation analysis, factor analysis, and multiple linear regression. All analyses were performed utilizing an IBM 360-40 computer with a core capacity of 128K. The reference document for the statistical programs and subroutines is IBM's Application Program Manual titled "System/360 Scientific Subroutine Package (360A-CM-03X) Version III Programmer's Manual (H20-0205-3)." No new or special programs were written for analyzing the data or establishing the relationships. Of course, the developed relationships presented later in this section can very easily be programmed for use with any computer.

Prior to developing the relationships, preliminary investigations were performed using correlation analysis and factor analysis. These techniques were used to select the explanatory or prediction variables that possibly would establish the best relationships with the pollutant concentrations.

Preceding the detailed description of the methodology used in the study is a recapitulation of factors which affect the storm water pollution regimen. Included is a discussion of the reasons for the investigation approach which was utilized by the study group.

General Considerations

The primary objective of the study was to develop functional relationships between various land use classifications and the amounts of pollution in urban storm water runoff. Land use classifications, along with land condition and precipitation, are used as input functions to generate pollutional loads and concentrations. Professional planners generally use such categories as residential land, commercial land, industrial land, open space, unused space, and so on. Each classification may be subdivided further, as, for example: single family residential, multifamily residential, retail commercial, office commercial, light industrial, and heavy industrial. Variables usually associated with these categories include: assessed valuation of the structures, population density, socioeconomic class, and employment density. For most purposes, the general classifications, the classification subdivisions, and the economic variables provide more than ample descriptions of specific areas. Other characteristics important in describing an urban area for the purpose of storm water runoff and pollution are: type of streets, type and condition of drainage conduits, topographic conditions, and so on. The primary source areas within a drainage shed are the paved sections, including streets, parking lots, roofs, and other impervious surfaces. As pointed out in the Chicago Study (4), the significant sources of storm water pollution can generally be restricted to the impervious portion of the drainage area. Therefore, it is important to use variables which either directly or indirectly relate to the imperviousness. Some possible choices might be the actual length and area of the streets. In commercial and industrial areas, possible elements might be the number of establishments, worker density, retail sales, and production figures. Information on these prime variables is not available in many cases, and secondary ones have to be used as measures of the imperviousness of drainage basins.

Before a pollution load is obtained, precipitation of some form is necessary. Variables associated with precipitation are the duration, amount, and intensity of individual precipitation events. The pattern and distribution of the event's occurrence act in conjunction with the antecedent moisture conditions within the particular drainage basin to cause variations in the rates, patterns, and volumes of runoff, and in the concentration level of the pollution parameters entrained in the runoff flows.

As the precipitation reaches the ground, it comes in contact with either a pervious or an impervious area. In an urban site, examples of impervious areas are streets, parking lots, and roofs, whereas examples of pervious areas are the bare or vegetally covered soils located within the urban basin. Generalizations of land use characteristics have been developed in terms of runoff and have been employed by engineers for many years to determine runoff (e. g., the rational formula written as $Q=CiA$ gives peak discharge when "C" represents a function of land use, "i" is the precipitation intensity, and "A" categorizes the drainage area). The precipitation which is unable to infiltrate the surface now transverses the surface until deposited into a channel which conveys it from the area. In this process, the runoff water entrains pollutional material from sources on the surface or within the channel.

Certain variables in the channel conditions affect the quality of the flow. For example, if a channel is open and unimproved, potholes and vegetation will catch organic material as the flow recedes, and hold it until the next flow flushes the decomposed or decomposing material farther down the channel. Laterals entering the main channel exert an influence on the amount of pollution entrained. Significant differences have been noticed between the storm water flow to the main channel via covered laterals attached to street inlets and via open ditches paralleling the streets.

Initially, one must consider the temporal condition of the watershed. The general sanitary conditions of the individual parcels influence the environment of the entire drainage basin. Some of the parcel indicators are the housing or establishment condition, the number of uncovered garbage cans, piles of rubbish and rubble, autos and animals maintained, the presence of privies, and the amount of litter in the streets which bound the parcel.

It is important to note that an area classified as residential or commercial in one section of an urban community is not the same environmentally as another area so classified. For example, in a new middle to upper class subdivision, the general environmental conditions are normally good to excellent. The yards are well-kept with no litter or piles of rubble. Furthermore, most individuals in these areas keep clean the portion of the street fronting their own property. A different section of the same community may have the same zoning and be classified the same, but may have entirely different environmental conditions due to the presence of the environmental deficiencies listed above.

Figure 23 presents a dispersed pollution flow chart. This chart details some of the groups of variables influencing the pollutional load as well as the runoff and flow reaching a receiving stream. It is linkages such as those partially illustrated in the table which complicate the prediction of the pollutional loads from an area. No one variable can be singled out which seems to influence the particular pollutant loads to the same degree for each event.

The sets of input variables selected to be investigated were: precipitation (current and antecedent events); environment (general sanitary conditions); and the geomorphological characteristics of the watershed (basin area, length of channel, relief, and land slope).

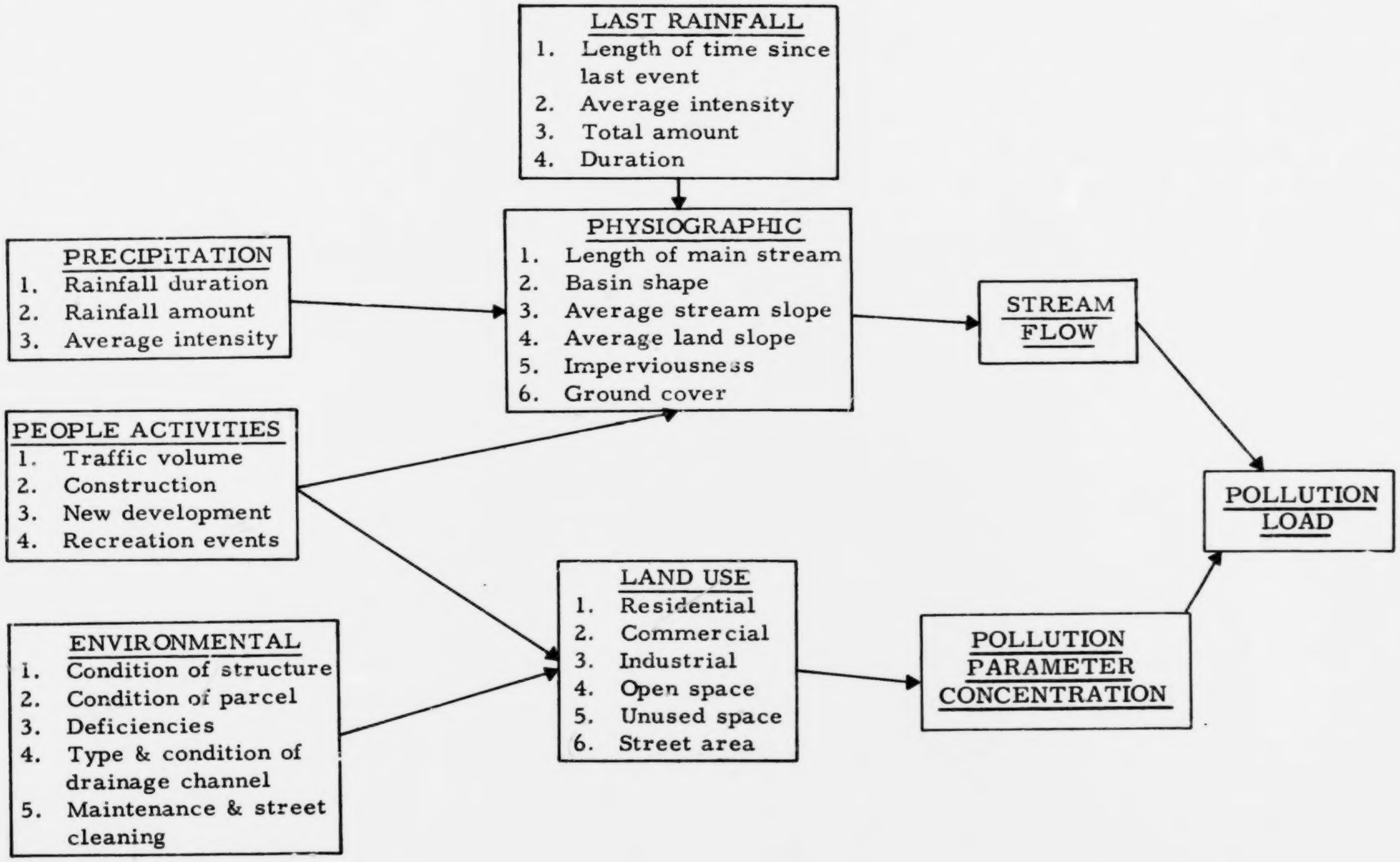
LAST RAINFALL
1. Length of time since last event
2. Average intensity
3. Total amount
4. Duration
PRECIPITATION
1. Rainfall duration
2. Rainfall amount
3. Average intensity
PHYSIOGRAPHIC
1. Length of main stream
2. Basin shape
3. Average stream slope
4. Average land slope
5. Imperviousness
6. Ground cover
STREAM FLOW
PEOPLE ACTIVITIES
1. Traffic volume
2. Construction
3. New development
4. Recreation events
POLLUTION LOAD
ENVIRONMENTAL
1. Condition of structure
2. Condition of parcel
3. Deficiencies
4. Type & condition of drainage channel
5. Maintenance & street cleaning
LAND USE
1. Residential
2. Commercial
3. Industrial
4. Open space
5. Unused space
6. Street area
POLLUTION PARAMETER CONCENTRATION

FIGURE 23 DISPERSED POLLUTION FLOW CHART

TABLE 52

POLLUTIONAL LOAD CRITERIA

Pollution Category	Measurable Parameter	Possible Sources
Bacterial	Total coliform Fecal coliform Fecal streptococcus	Humans Land mammals Birds
Organic	BOD COD TOC	Organic matter Leaves Grass clippings Humans and other animals Oil and grease
Nutritional	Nitrogen Phosphates	Fertilizers Leaching from minerals Decomposition of organic matter
Solids	Suspended solids Clay Silica Organic matter	Erosion of cleared land Dust and dirt from streets Unimproved drainage channels
	Dissolved solids Carbonates Chlorides Sulfates Phosphates Nitrates of calcium Organic matter	Erosion of cleared land Leaching from minerals Soluble dust and dirt from streets

The output variables descriptive of pollution are the various bacterial, organic, nutrient, and solids parameter concentrations and their associated loadings. Table 52 illustrates pollution categories, the measurable parameters, and the possible sources of the pollutants. This chart is not intended to present all of the possible sources, but only to indicate some of the most common ones. The investigation technique requires relating inputs to outputs from the homogeneous sections within the basins, and aggregating the results to obtain a value representative of the total drainage area.

Correlation Analysis

The values of the correlation coefficient (R) determined by standard correlation analysis were used to examine the degree (or intensity) of association among the study variables. Whereas the simple correlation coefficient always lies between -1 and +1, the multiple correlation coefficients range between 0 and 1. If the value of the coefficient is 0, the variation between the variables is unexplained. The results of the correlation analysis are shown in Tables 53 through 56.

The coefficients were tested against the null hypothesis that there was no correlation between the variables. This hypothesis is rejected for values greater than the 5 percent critical point.

Correlation matrices between independent variables are shown in Tables 53 and 54. Table 53 shows the associations between land use activities on the fifteen sites. As would be expected, the total area is correlated with the variables depicting the areas of various land use activities. It is felt that possibly the classifications of land use held by the TMAPC should be redefined. The land use categories should include only the area devoted to specific types of use. For example, a forty acre industrial site would not be listed just as a forty acre industrial parcel, but would be further delineated to include the street, open space, and transportation area, as well as the area devoted strictly to industrial activity.

The residential area is highly correlated with the street area and institutional area. This is understandable in that house sites are usually required to front on a street along at least one side of a parcel. Therefore, an increase in housing also produces an increase in street area. In like manner, discrete amounts of institutional area (school sites) are required at predictable intervals in the growth of residential areas.

TABLE 53

CORRELATION MATRIX LAND USE ACTIVITIES[a, b]

Symbol	Total Area (1)	Street Area (2)	Residential Area (3)	Commercial Area (4)	Industrial Area (5)	Institutional Area (6)	Transportation Area (7)	Open Space (8)	**Unused** Space (9)
(1)	1.0000	0.8162**	0.6682**	0.6327*	0.6125*	0.6874**	0.0280	-0.0571	0.6115*
(2)		1.0000	0.6707**	0.4113	0.2825	0.4992	0.1350	-0.2352	0.3262
(3)			1.0000	0.1556	-0.0616	0.6862**	-0.2471	-0.0410	0.1390
(4)				1.0000	0.5229*	0.6313*	0.0600	-0.0634	0.2939
(5)					1.0000	0.1551	0.0248	-0.2080	0.7799**
(6)						1.0000	0.0032	-0.1005	0.1344
(7)							1.0000	-0.1515	-0.1077
(8)								1.0000	-0.2180
(9)									1.0000

[a] Data input was the area of land use activities in acres in January 1969, for all 15 test areas.

[b] Levels of significance:

* 95 percent level

****99 percent level**

TABLE 54

CORRELATION MATRIX
SELECTED ENVIRONMENTAL AND LAND USE FACTORS[a, b]

Symbol	EI (1)	HI (2)	% Poor Housing (3)	Refuse Def. /Acre (4)	Total Def. Def. /Acre (5)	% Com. Use (6)	% Ind. Use (7)	% Res. Use (8)	% Arterial Streets (9)	Res. Density Peo. /Res. Acre (10)
(1)	1.000	0.926**	-0.831**	-0.944**	-0.962**	-0.007	-0.039	-0.118	-0.187	-0.517*
(2)		1.000	-0.882**	-0.810**	-0.833**	0.009	-0.129	0.032	-0.198	-0.426
(3)			1.000	0.826**	0.806**	-0.136	0.035	0.051	0.017	0.272
(4)				1.000	0.981**	-0.009	-0.094	0.179	0.258	0.571*
(5)					1.000	-0.007	-0.106	0.167	0.211	0.560*
(6)						1.000	0.111	-0.374	0.510	0.406
(7)							1.000	-0.464	-0.042	-0.129
(8)								1.000	-0.196	0.182
(9)									1.000	0.648**
(10)										1.000

[a] Levels of significance:
* 95 percent level
** 99 percent level

[b] Data taken from all 15 test areas

TABLE 55

CORRELATION COEFFICIENTS
ARITHMETIC MEAN OF PARAMETER CONCENTRATIONS VS. LAND USE VARIABLES[a]

Pollution Parameter		Independent Variables[b]				
		EI	Arterial Streets[c] (Acres/Acre)	Other Streets[d] (Miles/Acre)	Residential Density (Peo./Res. Acre)	Main Covered Storm Sewer[e] (mi)
Name	Symbol	X_1	X_{13}	X_{16}	X_{17}	X_{19}
Total coliform[f]	M_1	-0.856**	-0.264	0.634*	0.691**	0.303
Fecal coliform[f]	M_2	-0.192	-0.076	0.095	-0.155	0.100
Fecal streptococcus[f]	M_3	-0.058	-0.157	0.288	0.137	-0.030
BOD	M_4	-0.121	0.373	0.102	0.121	0.479
COD	M_5	-0.426	0.304	0.373	0.533*	0.550*
Organic Kjeldahl nitrogen	M_7	0.330	0.553*	0.139	0.236	0.022
Soluble orthophosphate	M_8	0.118	0.508	0.228	0.068	0.029
Total solids	M_9	0.116	0.555*	0.214	0.060	0.044
Suspended solids	M_{12}	0.102	0.554*	0.237	0.075	0.002
Specific conductance	M_{16}	0.031	0.242	0.046	0.147	0.269

[a] These correlation coefficients are based on 15 observations (All 15 test areas).

[b] Levels of significance:
- * 95 percent level
- ** 99 percent level

[c] Arterial Streets--Ratio of area of arterial streets to total area of the drainage shed.

[d] Other Streets--all streets except arterial streets.

[e] All covered interceptor storm sewer greater than 24 inches in diameter.

[f] Geometric mean by events.

TABLE 56

CORRELATION COEFFICIENTS[a, b] ARITHMETIC MEAN OF PARAMETER CONCENTRATIONS VS. SELECTED PERCENTAGE LAND USE VARIABLES

Pollution Parameter Name	Symbol	Other Streets % X_{22}	Residential Land % X_{23}	Commercial Land % X_{24}	Industrial Land % X_{25}	Open Space % X_{26}	Unused Space % X_{29}
Total coliform[c]	M_1	0.370	0.244	-0.061	-0.126	-0.350	0.060
Fecal coliform[c]	M_2	-0.050	-0.070	-0.075	0.514*	-0.095	-0.073
Fecal streptococcus[c]	M_3	-0.072	-0.137	0.043	0.094	0.192	0.199
BOD	M_4	-0.281	0.218	0.124	0.198	-0.128	0.137
COD	M_5	-0.044	0.037	0.160	0.279	-0.331	0.383
Organic Kjeldahl nitrogen	M_7	-0.548*	0.164	0.079	0.083	0.137	0.332
Soluble orthophosphate	M_8	0.455	0.229	0.017	0.660*	-0.100	0.788**
Total solids	M_9	0.401	0.379	0.041	0.728**	-0.049	0.733**
Suspended solids	M_{12}	0.384	0.424	0.055	0.736**	-0.021	0.708**
Specific conductance	M_{16}	-0.182	0.087	0.061	0.152	-0.044	0.028

[a] These correlation coefficients are based on 15 observations (All 15 test areas).

[b] Levels of significance:

- * 95 percent level
- ** 99 percent level

[c] Geometric mean by events

A significant amount of correlation exists between the commercial area and both the industrial and institutional areas. Although these relationships are expected when analysis is performed at the regional or metropolitan level, they were unexpected at the level of analysis in this study.

The correlation between industrial area and unused space can be explained partially by the usual associations of land uses. In areas with mixed uses and areas zoned for industrial use, vacant land waiting for development is classified as unused space. Its location is usually such that it is not economical to utilize it during the interim period for a higher order use, such as recreational land or even agricultural land.

Table 54 shows the relationships between selected environmental and land use variables. As would be expected, the environmental variables are highly correlated with each other. Residential density exhibits a significant correlation with three of the five environmental variables used. This relationship leads to the conclusion that higher population densities increase the probability of a poor environment.

The significant relationship between the arterial streets and residential density can be interpreted in view of classic zoning procedures. Arterial streets are usually strip zoned for commercial use. Parcels with multifamily or apartment units are ordinarily used as buffers between commercial areas and the areas which are restricted exclusively to single family dwellings.

Tables 55 and 56 show the correlation coefficients of the arithmetic averages (geometric averages for bacterial parameters) of the pollution parameter concentrations (by event) correlated against several land use and environmental variables. The tables are based on 15 observations (15 test areas) and include all of the land use classifications investigated on this project. Since each of the 15 watersheds considered is "homogeneous" as to land use, the only correlation coefficients that have meaning are the ones formed between variables common for all test areas. The common variables are: Environmental Index (X_1); unused space (X_{29}); other streets (X_{16} and X_{22}); arterial streets (X_{13}); and main covered storm sewer (X_{20}).

From the tables it can be seen that the two solids categories and the total coliform category had the most significant correlations. The variables which correlated with total coliform indicate that these all describe the general environmental factor of an area. This factor and its effects on the numbers of total coliform can be explained by the EI, residential density, and the length of other streets. The last category is also an indicator of residential density, in that there is a direct increase of street area with each increase in the number of residential dwellings.

The highest correlation coefficients formed with the solids categories are for the percentage of open space and industrial area and for the variable depicting arterial streets. Since this coefficient was developed with information from all test areas, the exceptionally high solids data from Test Area 1 may introduce a bias with respect to the variables depicting percentage of unused space and industrial area. The correlation with the amount of arterial streets can be interpreted in view of the fact that arterial streets are indicators of the degree of development. The imperviousness added by arterial streets correspondingly increases the amount and velocity of runoff, which act together to expand the solids load, either by scouring of channel banks or by greater flow entrainment of particles on the channel bed.

The COD concentration is significantly correlated with the residential density and the length of main covered storm sewer. Residential density may influence the COD value either through home maintenance functions performed for a large automobile population or through the observed study relationship that the high population density test areas were in older, residential sections which had greater amounts of vegetal cover. The decay products from this vegetal material may cause the higher COD loading. In the same manner, the greater the length of storm sewer within an area, the more probable the opportunity for decay of organic matter in the damp confines of the sewer.

The significant correlations of the variables for the percentage of industrial and unused area with soluble orthophosphate may be also biased by the high results from Test Area No. 1. The other significant correlations shown in the table are unexplainable at present.

Factor and Principal Component Analysis

A large number of variables can influence the types and amounts of pollutional loads flushed from an urban area during storms. In the initial stage of the study, variables thought to exert considerable influence on pollution were selected for measurement in hopes that, as the study progressed, the primary determinants of urban pollution could be identified.

These variables were grouped into one of two major classifications. One classification was composed of variables which pertained to the precipitation regimen. This regimen produces the driving force which extrudes the pollution from its source and geographically redistributes it in a manner which has been deemed unsuitable for man's environment. The other classification pertained to characteristics of the land surface, and included factors, both naturally occurring and those caused by man, which could react with precipitation to produce an undesirable pollutional condition at a point downstream or downslope from the area at which the characteristic is located. The models developed with data sets from the two classifications were deterministic since the hydrological and demographical categories were specified.

The multivariate methods of factor and principal component analysis were used to examine the variables in the land surface classification. Both methods have been used previously in various fields of study. Factor analysis has been used in geology (17), hydrology (18), and water quality (19). Principal component analysis has been applied to problems in econometrics (20) and water resources (21). Factor analysis was used to determine the degree of grouping and importance of the groups when a number of different variables were lumped together. This form of analysis served as an aid in selecting variables for regression studies in that it delineated the variables which accounted for the most variance within the factors. The principal components method was used to determine index numbers from data on groups of land based variables for each test area. These index numbers were then compared with the measured pollution loads obtained by sampling.

The computer program given in Version III of IBM's SSP/360 was used to perform factor analysis on the selected variables. An intermediate step in the program was the computation of eigenvalues and eigenvectors from the correlation matrix of the variables which were studied together.

The 36 variables measured for this portion of the study could loosely be grouped into classifications which pertained either to drainage, environment, land use, or public utility decisions (i. e., covered storm sewers). Factor analysis was performed on each of the four groups. The results for the analysis of the drainage characteristics are shown in Table 57.

The rotated factor matrix contains three factors which together explain 87.77% of the variance exhibited by the seven variables.

TABLE 57

ROTATED FACTOR MATRIX OBTAINED BY FACTOR ANALYSIS OF SELECTED DRAINAGE CHARACTERISTICS OF THE TEST AREAS

Variable	Loadings Factor 1	Factor 2	Factor 3
Area	0.9549	-0.1562	0.0263
Length of main channel	0.8339	0.0970	0.3558
Length of main channel to centroid of area	0.8866	-0.0181	0.2117
Fall of watershed	0.5163	0.1098	0.7489
Average main channel slope	-0.1857	0.9057	0.2758
Average land slope	0.1806	-0.0516	0.9145
Impervious cover	0.1621	0.7974	-0.4904
Explained covariance (%)	39.33	21.50	26.94
Cumulative covariance (%)	39.33	60.83	87.77

The first factor, which explains 39.33% of the variation, is dominated by the variable of watershed area. Two other variables influence the factor at slightly lower levels. These variables are the total length of channel, which is a measure of the drainage density of the watershed, and the length of the main channel to the point nearest the centroid of the basin, which is an indicator of the catchment shape. The second factor, explaining 21.50% of the variance, is ordered by the variable of channel slope with contributions from the variable of area imperviousness. The third factor, which accounts for 26.94% of the variation, is controlled by the land slope variable. An important secondary influence is exerted by the variable of watershed relief.

The loadings of the factors can be interpreted when several drainage basins are examined. The sites with large values for the first factor can be expected to produce larger volumes of runoff than the sites with lower values. The second factor is a measure of relief and urban development. The sites with larger values can be expected to produce greater velocities of flow and higher percentage increases in peak flow than the sites with lower values. High values for the third factor indicate greater relief or ruggedness of the site, and, therefore, greater erosional capability.

After examination of the grouped factor runs, 22 variables from the four major classifications were selected, and factor analysis was performed. Eight factors which together explained 95 percent of the variation were computed. The variables within the factor that exhibited the most influence on the factor were used in regression analysis; the results are shown in Table 58.

The eigenvectors or principal components from this run were used to compute an index value for each site. The variables and the values of the first two eigenvectors are shown in Table 58. The first eigenvector exhibits high factor loadings on the variables affecting the environment. The second shows the most important loadings on the first four drainage characteristics and the public utility decision variable, which measures miles of main covered storm sewer on the watershed. The values for the 22 variables used in the analysis were standardized. The standardized values for each site were multiplied by the corresponding numerical coefficient in the eigenvector and summed to obtain an index value for the site. The index numbers for each site are shown in Table 59.

The index values for the components were ranked and compared with ranks obtained from pollutional measures made for the test areas. The

TABLE 58

VARIABLES AND ASSOCIATED EIGENVECTOR VALUES USED TO COMPUTE THE INDEX VALUES FOR THE STUDY SITES

Variable		1st Principal Component	2nd Principal Component
1	Refuse	0.36127	0.10051
2	Burners	0.35496	0.11619
3	Rubble	0.36271	-0.02609
4	Lumber	0.35921	-0.00353
5	Old autos	0.35347	0.13199
6	Poor sheds	0.32949	-0.05824
7	Main covered storm sewer	0.13460	0.40421
8	Covered sewer/total length	0.18760	0.13939
9	Arterial streets	0.08249	0.05688
10	Other streets	0.19831	-0.07006
11	Residential land	0.08092	-0.09034
12	Commercial land	0.07502	0.18551
13	Area	-0.01697	0.46560
14	Length of main stream	-0.11978	0.36973
15	Length of main stream to point nearest centroid of area	-0.11322	0.42643
16	Fall of watershed	-0.11776	0.31144
17	Average main channel slope	-0.08598	0.06116
18	Average land slope	-0.23110	0.15944
19	Impervious cover	0.03932	0.02437
20	Institutional land and open space	-0.16610	-0.01390
21	Unused space and transportational land	-0.06838	-0.04938
22	Industrial land	-0.04273	0.23796

TABLE 59

INDEX VALUES FOR STUDY SITES FROM PRINCIPAL COMPONENTS

Test Area No.	Index No. from 1st Principal Component	Index No. from 2nd Principal Component
1	-2.034	+2.497
2	-0.835	-0.506
3	-1.583	+0.504
4	-0.517	+3.626
5	-1.600	+1.660
6	+0.599	+0.288
7	-0.657	-1.645
8	+0.541	-1.041
9	+6.474	-1.958
10	-0.360	-0.009
11	+4.993	+3.604
12	-0.635	-2.439
13	-1.613	-0.573
14	-2.881	-0.469
15	+0.996	-3.015

TABLE 60

STUDY SITE ENVIRONMENTAL RANKINGS[a]

			Rankings Based On:				
Test Area No.	Index No. from 1st Principal Component	EI[b]	BOD Load (lb. /acre/year)	COD Load (lb. /acre/year)	Total Coliform Geometric Mean (number/100 ml)	Fecal Coliform Geometric Mean (number/100 ml)	Fecal Strep. Geometric Mean (number/100 ml)
1	2	1-3	10	10	7	11	5
2	6	4-5	9	7	5	13	2
3	5	7-8	2	4	8	14	12
4	9	10-11	14	14	2	10	10
5	4	4-5	11	11	11	12	4
6	12	13	5	8	10	15	14
7	7	6	3	3	4	2	3
8	11	12	12	12	13	8	7
9	15	14	4	9	15	4	9
10	10	9	15	15	9	5	15
11	14	15	13	13	14	9	8
12	8	1-3	7	5	6	1	1
13	3	7-8	6	6	3	3	6
14	1	1-3	1	1	1	7	13
15	13	10-11	8	2	12	6	11

[a] Sites ranked in order from best (rank = 1) to poorest (rank=15).

[b] Multiple entries indicate that several sites have equal EI values.

TABLE 61

STUDY SITE RANKINGS IN RELATION TO DRAINAGE CHARACTERISTICS[a]

Test Area	Rankings Based On:		
	Index No. from 2nd Principal Component	COD Load (lb. /acre/year)	Total Solids Load (lb. /acre/year)
1	13	10	15
2	7	7	10
3	11	4	11
4	15	14	14
5	12	11	1
6	10	8	3
7	4	3	7
8	5	12	9
9	3	9	8
10	9	15	13
11	14	13	12
12	2	5	4
13	6	6	6
14	8	1	5
15	1	2	2

[a] Sites ranked from best (rank=1) to poorest (rank=15).

rankings from the first principal component were compared with rankings of BOD, COD, total coliform, fecal coliform, fecal streptococcus, and a calculated EI described in Section 6 of this report. The results are shown in Table 60. This method appears to have promise as a means of classifying an area as to bacterial output. The same procedure was used for drainage characteristics; results are given in Table 61. The sites with larger values for the index computed from the second eigenvector should produce greater loads of total solids and, possibly, COD per acre than other sites with lower indexes.

This method lends itself to survey techniques once pollutional loads have been measured in a base watershed within an area. Information from maps, municipal authorities, and local health departments is applied in place of sampling to compare urban drainage basins. The procedure can be used to compute and compare pollutional loads between the base sites and the sites already developed. Planners can utilize the method to determine what the pollutional loads will be from future developments under different land uses. However, additional work is needed to determine whether these variables adequately describe the test areas, or whether others are required. This can be regarded as continuing example of the expanding quantitative aspects of the planning process.

Regression Analysis

This type of analysis was performed to construct models for predicting or estimating the pollution parameter concentrations. Both univariate and multivariate regression methods were used. Since multiple regression is but an extension of the methodology for univariate analysis, the defining equation will be for the former type.

The equation for the multiple linear regression model is:

$$Y=b_o + b_1X_1 + b_2X_2 + --- + b_kX_k + u \qquad (10\text{-}1)$$

where Y is the dependent variable, X_i (i=1 to k) represents an explanatory variable, b_i (i=1 to k) represents a regression coefficient, and u is an unexplained residual term. There are n of these equations.

In this case, the Y's are the pollution parameter concentrations. Specific symbols used to represent these concentrations for individual observations are designated Y_i's, while M_i's represent the arithmetic averages[2] (by events) of all observations from each test area.

The X_i's are the independent variables which for this study depict precipitation, land use, environment (land parcel sanitary conditions), and drainage characteristics.

Factor analysis was used to indicate the independent variables most suitable for univariate regression analysis. The symbols and units for the dependent and independent variables used in this analysis are listed in Table K-1 in Appendix K. Neither all the pollution parameters measured in the study nor all the independent variables were used in this analysis. From the independent variables in Table K-1, the most promising groupings of variables for multiple regression analysis were selected by the additional use of factor analysis. No regression analysis was performed with all the study variables grouped together.

The correlation coefficient (R) and the coefficient of multiple determination (R^2) are possible criteria for the selection of the most reliable equations. However, a high R^2 value (close to unity) can often be misleading. This is particularly true when only a small number of observations are used, because the increase in the number of variables may have more of an influence on the accompanying increase in R^2 than the related explanation contributed by the variables. Since the equations developed from this study include a maximum of only 15 test areas (this corresponds to a maximum of 15 observations), large R^2 values may not be the best criteria for selection.

The F-value, which is the ratio of the regression mean square to the residual mean square, is not necessarily a measure of the equation's usefulness as a predictor. A significant F-value means only that the regression coefficients explain more of the variations in the data than would be expected by chance a specified percentage of time under similar conditions. The level of significance selected for regression analysis in the study was 95 percent.

It should also be noted that the use of the F-test requires that the residuals be normally distributed. This distribution cannot be arbitrarily assumed to exist for hydrologic data or data on the concentration levels of the pollution parameters. Regression analysis, however, can be used regardless of whether the data set is from a normal distribution.

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[2] Geometric averages for bacterial parameters.

The regression analysis was performed separately on each of the two classifications mentioned previously in the discussion of factor analysis. Utilization of the equations developed in the analysis of the precipitation data would enable pollution loads to be predicted on an event basis. The use of equations derived from land use data would enable planners to evaluate the average pollutional loads that could be expected from a site with certain land surface characteristics.

Precipitation Regimen - As has been discussed, the variables depicting the precipitation regimen are among the most important in analyzing the pollutional characteristics of an urban area. Two groups of independent variables were developed to examine the influence of precipitation. These were (1) those concerning data taken during the current event and (2) data items from the antecedent event. The two categories had the following associated variables:

Current Event	Antecedent Event
Time since start	Time since antecedent event
Antecedent amount	Amount of antecedent event
Average intensity	Duration of antecedent event
	Average intensity of antecedent event

It was reasonably assumed that the various pollution parameter concentrations (and thus pollution loads) at a particular time during a precipitation event are functions of one or more of the variables included in the above classifications. Data for these variables were calculated for each sample. The values are shown in Table M-2 of Appendix M.

The procedures used in these calculations were:

- Time since start (Z_1)--The length of time in hours from the start of rainfall to the starting time of a composite sample or the time of a grab sample.

- Antecedent amount (Z_2)--The total accumulated amount of precipitation in inches that had occurred from the beginning of rainfall to the sample collection time.

- Average intensity (Z_3)--The average intensity in inches per hour. This value was obtained by dividing the accumulated amount by the time since start. It should be noted that this value, as well as the antecedent amount for samples collected after a rainfall has ended, remains the same for all samples collected after the stop of the rainfall.

- Time since antecedent event (Z_4)--The time in hours that had elapsed from the end of the previous precipitation event over 0.10 in. to the starting time of the current event or the event being sampled. This value does not change for the individual samples collected during the current event.
- Amount of antecedent event (Z_5)--The total amount of the antedent event in inches.
- Duration of antecedent event (Z_6)--The duration of the antecedent event in hours.
- Average intensity of the antecedent event (Z_7)--The average intensity of the antecedent event in inches per hour.

All the above precipitation variables except Z_6 were investigated by scattergram plotting, univariate linear regression, and multiple linear regression. The dependent variables were concentrations of the pollution parameters. The results of the univariate and multivariate regression analysis are shown in Table K-2 in Appendix K.

As can be seen from an examination of the table, there is at least one significant univariate equation that could be used to predict the pollutant concentration of each of the parameters. Significant multiple regression equations are also available to use with each of the parameters, with the exception of total solids. The deficit in this category is understandable since total solids is primarily dependent on the velocity of flow. The only factor of the six remotely related to the velocity of flow is Z_3 (the antecedent average intensity), and its effect on the significance level of the multiple equation in which it appears is noticeable.

The examination of the precipitation variables was extended further to include an analysis of the BOD concentration measured on the rising limb of the runoff hydrograph for each test area. The BOD observations were transformed to natural logarithms, and multiple linear regression was run against both the current and antecedent precipitation variables. It was hoped that the analysis would further characterize the test areas by grouping them by similar equations. Table 62 shows the correlation coefficients which were obtained in this analysis.

TABLE 62

CORRELATION COEFFICIENTS
ln BOD VS. RISING LIMB PRECIPITATION VARIABLES[a]

Test Area No.	Current Precipitation Variables				Antecedent Precipitation Variables			
	Z_1	Z_2	Z_3	Z_1, Z_2, Z_3[b]	Z_4	Z_5	Z_7	Z_4, Z_5, Z_7[b]
1	-0.594*	-0.642*	-0.031	0.651	-0.663*	-0.186	0.576*	0.750
2	-0.560*	-0.711**	-0.363	0.788*	-0.053	-0.067	0.303	0.603
3	-0.269	-0.350	-0.009	0.356	-0.142	0.034	0.398*	0.430
4	-0.511**	-0.653**	-0.666**	0.713**	0.202	0.199	-0.169	0.320
5	0.470*	-0.166	-0.431	0.650*	-0.056	0.218	-0.550**	0.829**
6	-0.595	-0.753*	-0.142	0.753	-0.776**	0.676*	0.812**	0.906*
7	-0.496	-0.652*	-0.244	0.684	-0.206	-0.040	0.433	0.566
8	0.384	-0.150	-0.454	0.475	0.592	0.286	0.061	0.958*
9	-0.915**	-0.535	0.262	0.930**	-0.697*	0.395	0.199	0.857*
10[c]	0.725*	-0.433	-0.771*	0.833**				
11	0.386	0.518	0.285	0.770	0.145	-0.662*	-0.553	0.743
12	-0.405	-0.860**	-0.407	0.893**	0.434	0.064	0.299	0.441
13	-0.760*	0.699*	-0.637	0.848	-0.138	-0.397	-0.212	0.457
14	0.552*	0.200	-0.508*	0.566	-0.207	0.727*	0.257	0.916**
15	-0.356	-0.636**	-0.438*	0.678*	0.047	0.108	-0.612**	0.759**

[a] Legend:

Z_1 = Time Since Start of Rainfall (hr.)
Z_2 = Cumulative Amount of Precipitation (in.)
Z_3 = Avg. Intensity Preceding Sample Collection (in. /hr.)
Z_4 = Time Since Antecedent Event (hr.)
Z_5 = Amount of Antecedent Event (in.)
Z_7 = Average intensity of Antecedent Event (in. /hr.)

[b] Correlation coefficients for multiple regression equations using all three listed independent variables.

[c] Antecedent selections were skipped because of singular matrix.

The time since start of rainfall (Z_1) and the cumulative amount of precipitation (Z_2), which are both current precipitation variables, are the most influential factors on the BOD concentrations.

Table K-3 shows the multiple regression equations developed from the current precipitation variables. The equations exhibit considerable variation between the test areas. The most consistent variable (as to sign) among the test areas was Z_2. This variable is directly related to the flow at the time of sample collection. The predominating negative coefficient indicates that a decrease in concentrations shown in the equations is more than offset by the greater volumes of runoff occurring between the start of runoff and the peak flow.

Land Surface Characteristics - These characteristics as defined have included 3 categories of variables: (1) land use, (2) environment, and (3) drainage. Land uses depict various land activities, such as residential, commercial, industrial, recreational, and institutional. The environmental variables are indicators of the general sanitary conditions of a parcel of land and include such factors as state of housing, refuse deficiencies, piles of rubble, and so on. Drainage variables are geomorphic factors which aid in defining the drainage characteristics of the watershed. The data items considered for this analysis were determined as follows:

1. The test area parameter concentrations were calculated by first averaging all sequential samples taken during any one precipitation event and then averaging these results with the grab sample results from other events which were sampled. The mean value so obtained was considered to be the representative concentration that would be found in storm runoff from the test site. All of the dependent variable input consisted of arithmetic averages except for the bacterial parameters, which were calculated in terms of geometric means. The averages were denoted as M_i's.

2. The land surface characteristics which were the independent variables in the analysis were calculated from the data presented in Sections 5 and 6. The X_i's in the equations specify the land use and environmental characteristics, while the D_i's represent the drainage characteristics.

A complete listing of the symbols and units for each of the dependent and independent variables considered for study is shown in Appendix H. Factor analysis was used to eliminate those variables which were either similar to others in effect or which could be replaced by other variables which explained more of the variations.

Regression analysis was performed using four sets of input data. The data sets utilized were:

1--All 15 test areas taken together
2--All test areas except 1, 12, and 14
3--Residential Test Areas No. 3, 5, 7, 8, 9, 13, and 15
4--Commercial and Industrial Test Areas No. 1, 2, 4, 6, 10, and 11

In data set 2, Test Areas No. 1, 12, and 14 were omitted because these watersheds were considered non-typical for the urban area. Test Area No. 1, which was undergoing development, recorded extremely high solids and phosphate averages. Test Area No. 14 was eliminated because of the small impoundments located along the drainage channel. The influence of the airport runways and adjoining open land of Test Area No. 12 was also considered to be minor, since only small amounts of land are usually devoted to this use in the typical urban area.

In data set 4, the regression equations for solids and soluble orthophosphate may be misleading due to the inclusion of Test Area No. 1. As mentioned, this test area was undergoing development, and the high solids and phosphate values obtained may be nonrepresentative of developed industrial areas.

Univariate and multiple regression analyses were performed. The equations were evaluated by correlation coefficients and F-values. The selections of the best results are shown in Tables K-4 through K-7 in Appendix K.

The results of the univariate analysis with the land use variables of all 15 test areas are shown in Table K-4. Significant equations were obtained for prediction of COD, organic Kjeldahl nitrogen, soluble orthophosphate, total solids, and total coliform.

Tables K-5, K-6, and K-7 present a selection of regression equations developed from data sets 2, 3, and 4, respectively. Data set 2, which includes data from both the residential and the commercial and industrial land use groups, was analyzed by univariate and multiple regression. The results are shown in Table K-5. The most interesting finding was the importance that can be attached to the significant influence of both the natural drainage characteristics as depicted by the D_i's and the man-made drainage characteristic X_{20} (ratio of the

TABLE 63

SUMMARY OF OCCURRENCE AND FREQUENCY OF SIGNIFICANT[a] VARIABLES DETERMINED BY REGRESSION ANALYSIS OF LAND SURFACE CHARACTERISTICS

Dependent Variables	Independent Variables																	
	X_{11}	X_{13}	X_{14}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}	X_{22}	X_{24}	X_{25}	X_{29}	D_1	D_2	D_3	D_4	D_6	D_9
Total coliform	6			1	3		2			1								1
Fecal coliform	1						2											1
Fecal strep.			1															
BOD														1				
COD	2				1	1		2						2				
TOC	1					1									1			
Organic Kjeldahl nitrogen	1	1			1		3		1							1	3	
Soluble orthophosphate											1	1				1		
Total solids		1									1	2	1			1		
Suspended solids			1								1	2						

[a] Significance ≥ 95 percent level

TABLE 64

MIXED-USE REGRESSION EQUATIONS FOR SAMPLE CALCULATIONS[a]

Regression Equation[b]	Correlation (R)	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)			
$M_1 = 565 - 420 (X_1) - 49.3 (X_{20}) - 6.70 (D_9)$	0.885	9.67**	K-97
COD (mg/l)			
$M_5 = 71 - 45.4 (X_1) + 2.61 (X_{21}) + 0.0062 (D_2)$	0.839	6.32*	K-109
Organic Kjeldahl Nitrogen (mg/l)			
$M_7 = 0.23 - 0 (X_{17}) - 0.029 (X_{20}) + 0.256 (D_6)$	0.887	9.81**	K-121
Total Solids (mg/l)			
$M_9 = 130 + 8.99 (X_{20}) + 2.59 (X_{22}) + 2.06 (D_4)$	0.690	2.42	K-129

[a] Equations developed using all test areas except 1, 12, and 14.

[b] Legend for dependent and independent variables:

M_i = Arithmetic mean (by events) of parameter concentration (geometric mean by events for total coliform)
D_2 = Length of main stream (ft.)
D_4 = Fall of drainage area (ft.)
D_6 = Average land slope (%)
D_9 = Form factor (dimensionless)
X_1 = Environmental Index (dimensionless)
X_{17} = Residential density (people/res. acre)
X_{20} = Covered sewer/total length (ratio)
X_{21} = Arterial streets (%)
X_{22} = Other streets (%)

[c] Levels of significance:

* 95 percent level
** 99 percent level

covered sewer to the total length of storm sewer) on the pollution parameters. There is at least one significant equation in each of the following categories: total coliform, fecal coliform, BOD, COD, organic Kjeldahl nitrogen, soluble orthophosphate, and total solids.

Tables K-6 and K-7 show the results from the separate analysis of the residential and the commercial and industrial land use areas. Significant regression equations for the residential test areas were found for only the total coliform and COD categories. In the analysis of the commercial uses, significant equations were developed in the total coliform, fecal coliform, fecal streptococcus, TOC, organic Kjeldahl nitrogen, total solids, and suspended solids categories.

The variables and frequency of their occurrence in the 39 significant regression equations found in the analysis are shown in Table 63. Most of the data concerning the 18 independent variables in this table can be obtained either from maps or from files of the planning and action agencies of the subject municipality. The calculation of the Environmental Index may require the assistance of the local public health agency if data on a past environmental survey is not available for use. This group of equations or a selection of equations from this group can be used to obtain a first order estimate of the storm water pollution loads in an urban area other than Tulsa if the precipitation regimen is similar.

The use of these equations is illustrated in Table 64. Calculations with these equations using the minimum and maximum values of the Tulsa test areas are presented. This is done to show the predictable range of pollutant concentrations obtained within the test data. Also included are examples showing the use of data from individual test areas.

Sample Calculations

1. Total Coliform

The multiple regression equation for total coliform (mixed use) is:

$$M_1=565-420\ (X_1)\ -49.3\ (X_{20})\ -6.70\ (D_9)$$

For an area with good environment (X_1=EI=1.00), this equation reduces to:

$M_1 = 145 - 49.3\ (X_{20}) - 6.70\ (D_9)$

The ranges of values for X_{20} and D_9 are:

Symbol	Min.	Max.	Item
X_{20}	0.61	3.78	Covered sewer/total length
D_9	0.82	2.85	Form factor

At maximum values for X_{20} and D_9, the calculated M_1 is negative:

$M_1 = 145 - 49.3\ (3.78) - 6.70\ (2.85) = -60$

Consequently, this regression equation is not suited to the prediction of total coliform concentrations near the maximum values for X_{20} and D_9 listed above.

For a bad environment (EI=0), the regression equation would be:

$M_1 = 565 - 49.3\ (X_{20}) - 6.70\ (D_9)$

Using minimum values for X_{20} and D_9, the maximum total coliform concentration would be:

$M_1 = 529$ (This compares with the highest value from the 15 test areas of 400.)

For Test Area 9, for example:

$M_1 = 565 - 420\ (0.23) - 49.3\ (1.59) - 6.70\ (1.47) = 380$, which compares favorably with the actual value of 400.

2. COD

The COD equation (mixed use) is:

$M_5 = 71 - 45.4\ (X_1) + 2.61\ (X_{21}) + 0.0062\ (D_2)$

For EI=1.00 (good environment):

$M_5 = 26 + 2.61\ (X_{21}) + 0.0062\ (D_2)$

For EI=0 (bad environment):

$M_5=71 + 2.61 (X_{21}) + 0.0062 (D_2)$

The ranges of values for X_{21} and D_2 are:

Symbol	Min.	Max.	Item
X_{21}	0	18.93	% Arterial streets
D_2	2170	11,200	Length of main stream (ft.)

For EI=1.00:

The minimum COD would be:

$M_5=26 + 0.0062 (2170) = 39$ (minimum from test sites studied: 42)

For EI=0:

The maximum COD would be:

$M_5=71 + 2.61 (18.93) + 0.0062 (11200) = 190$ (maximum from test sites studied: 138)

For Site 12:

$M_5= 71 -45.4 (1) + 2.61 (3.94) + 0.0062 (5710) = 61$ (actual value: 45)

For Site 5, a residential test area:

$M_5= 71 -45.4 (0.99) + 2.61 (3.94) +0.0062 (11200) = 106$ (actual value: 138)

One can conclude that this equation can be a somewhat useful predictor, even near the limits of some of the independent variables.

3. Organic Kjeldahl Nitrogen

The regression equation (mixed use) is:

M_7=0.23-0 (X_{17}) -0.029 (X_{20}) + 0.256 (D_6) (Independent of X_{17})

The ranges of values for X_{20} and D_6 are:

Symbol	Min.	Max.	Item
X_{20}	0.61	3.78	Covered sewer/total length
D_6	0.75	4.60	% Land slope (At D_6=0, the land slope would be at a minimum)

For D_6=0, the equation would be:

M_7=0.23-0.029 (X_{20})

The minimum value from this equation (at X_{20}=3.78) would be:

M_7=0.23-0.029 (3.78) = 0.12

If there were no covered sewers (X_{20}=0), on the other hand, the nitrogen concentration would depend only upon the land slope:

M_7=0.23 + 0.256 (D_6)

For a 4.6% land slope (maximum of test areas studied):

M_7=0.23 + 0.256 (4.6) = 1.41

For Test Area 6:

M_7=0.23-0.029 (3.78) + 0.256 (2.19) =0.68 (actual value: 0.65)

For Test Area 13:

M_7=0.23-0.029 (0.55) + 0.256 (4.60) = 1.39 (actual value: 1.46)

For mixed land use, this regression equation was one of the most accurate ones obtained.

4. Total Solids

The best multiple regression equation for total solids (mixed use) is:

$$M_9 = 130 + 8.99\ (X_{20}) + 2.59\ (X_{22}) + 2.06\ (D_4)$$

The ranges of values for the independent variables are:

Symbol	Min.	Max.	Item
X_{20}	0.00	3.78	Covered sewer/total length
X_{22}	0.00	35.80	% Other streets
D_4	30	186	Fall of drainage area (ft.)

Using these limits, the corresponding minimum value for total solids would be:

$$M_9 = 130 + 8.99\ (0.61) + 2.59\ (0.00) + 2.06\ (30) = 197 \text{ mg/l}$$
(minimum of test areas studied = 199)

The maximum would be:

$$M_9 = 130 + 8.99\ (3.78) + 2.59\ (35.80) + 2.06\ (186) = 640 \text{ mg/l}$$
(maximum of test areas studied = 2242)

For Test Area 1:

$$M_9 = 130 + 8.99\ (0.61) + 2.59\ (7.72) + 2.06\ (113) = 388 \text{ mg/l}$$
(actual value: 2242 mg/l)

For Test Area 12:

$$M_9 = 130 + 8.99\ (0.00) + 2.59\ (0.00) + 2.06\ (58) = 249 \text{ mg/l}$$
(actual value: 199 mg/l)

For extreme cases, therefore, this regression equation is of only limited usefulness.

It is obvious that these models, as well as most multiple regression equations, have definite boundary limits for the input independent variables. In addition, it cannot be overemphasized that extrapolation of the statistically fitted function beyond the range of values of the predictor variables may lead to erroneous results for the dependent parameter. If one strictly follows statistical results, regression equations with the largest coefficients of multiple correlation should be used as the "best" equations. However, due to the errors inherent in sampling, analysis, and data handling, the equations (models) which give the best explanations are preferred. Thus, statistical results are used as much as possible within the limitations of rational judgments.

The utilization and demonstration of a few of the test equations in this section have shown that the equations will not be suitable for predicting pollutant concentrations in all cases. As found in the example for total coliform, the values of variables and the mix of variable values in the equations, even though within the range of numbers found in Tulsa, will not give reliable answers in certain combinations. Judicious caution must be exercised in the intrepretation of equation results. When obviously wrong results are obtained with the best equations, it is recommended that other equations from Appendix K be utilized and the results compared with those obtained using the best equations.

SECTION 11

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SECTION 12

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SECTION 14

GLOSSARY AND ABBREVIATIONS

Glossary

Antecedent Precipitation Index (API) - An indicator of the amount of water (in inches) present in the soil at any given time. The calculation of the API is based on the assumption that, during time periods of no precipitation, the soil moisture decreases logarithmically with time.

Baseline Sample - A sample collected during dry-weather flow (i. e., it does not consist of runoff from a specific precipitation event).

Covered Sewer/Total Length - The ratio of the total length of covered storm sewer (conduits <24 in. diameter omitted) to the total length of the main channel (L or D_2).

Dependent Variables - The dependent variables in this study are the chemical and bacterial pollution parameters measured in the laboratory.

Environmental Index (EI) - An indicator of environmental quality derived and explained in Section 6.

Form Factor (FF) - An indicator of the drainage characteristics of a watershed defined in Table 17, Section 5.

Independent Variables - The independent variables in this study are the precipitation, drainage, land use, and environmental characteristics which were related to the dependent variables by correlation analysis and regression analysis.

Pollution Parameters - The chemical and bacterial quantities measured in the laboratory to indicate pollution levels.

Precipitation - Includes all forms--such as rain, snow, sleet, etc.

Precipitation Event - A continuous fall of precipitation having a water equivalent greater than or equal to 0. 10 in.

Abbreviations

A	Area
Ant.	Antecedent
API	Antecedent precipitation index
BOD	Biochemical oxygen demand (5-day, 20° C)
Bus.	Business
C	Percent impervious cover
Cl	Chloride
COD	Chemical oxygen demand
Col.	Coliform
Com.	Commercial
Commun.	Community
Cond.	Specific conductance (micromhos/cm)
Def.	Deficient, deficiency
Dist.	District
DS	Dissolved solids
EI	Environmental Index
Exc.	Excellent
F.	Fecal
FF	Form factor
FY	Fiscal year
G	Geometry number

H	Fall of watershed
HI	Housing Index
Ind.	Industrial
Indiv.	Individual
Inst.	Institutional
L	Length of main stream
L_c	Length of main stream to centroid of test area
Med.	Medium
Mem.	Memorial
MF	Membrane filter
MG	Million gallons
mg	Milligrams
mgd	Million gallons per day
MPN	Most probable number
N	Organic Kjeldahl nitrogen (does not include ammonia)
n. d.	No data
P	Phosphorus
Peo.	People
pH	Negative logarithm of hydrogen ion concentration
PHS	Public Health Service
Prec.	Precipitation
Pred.	Predominantly

Quan.	Quantity
R	Correlation coefficient
R_n	Relief number
Ref.	Reference
Res.	Residential
S_c	Average main channel slope
S_1	Average land slope
SMSA	Standard Metropolitan Statistical Area
SS	Suspended solids
Std. Dev.	Standard deviation
Strep.	Streptococcus
Struct.	Structure
Sus.	Suspended
T.	Total
TMAPC	Tulsa Metropolitan Area Planning Commission
TOC	Total organic carbon
Trans.	Transportational
TS	Total solids
U.S.D.A.	United States Department of Agriculture
U.S.G.S.	United States Geological Survey
Vac.	Vacant
VDS	Volatile dissolved solids
VSS	Volatile suspended solids

SECTION 15

APPENDICES

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APPENDIX A

URBAN STORM WATER RUNOFF TEST AREAS

The following pages include pictorial descriptions of the fifteen test areas selected for sampling and analysis. The residential test areas (3, 5, 7, 8, 9, 13, and 15) are typical of broad categories of various types of single-family living. Although all are zoned U-1C Restricted Residence District, there are many differences among the test areas as to streets, tree and ground cover, age of addition, and general environmental conditions. Whereas Test Area 2 is typical of neighborhood shopping districts in large metropolitan areas, Test Area 10 is an example of a central business district. The industrial areas (1, 4, 6) are typical of developing light, medium, and heavy industrial areas. Test Area No. 11 consists mainly of very low-income residential areas, but has strip commercial activity on the arterial streets. Test Area No. 14 is a golf course typical of all urban areas.

Table A-1 presents a summary of the zoning classifications.

TEST AREA NO. 1

SOUTHERN MEMORIAL INDUSTRIAL DISTRICT

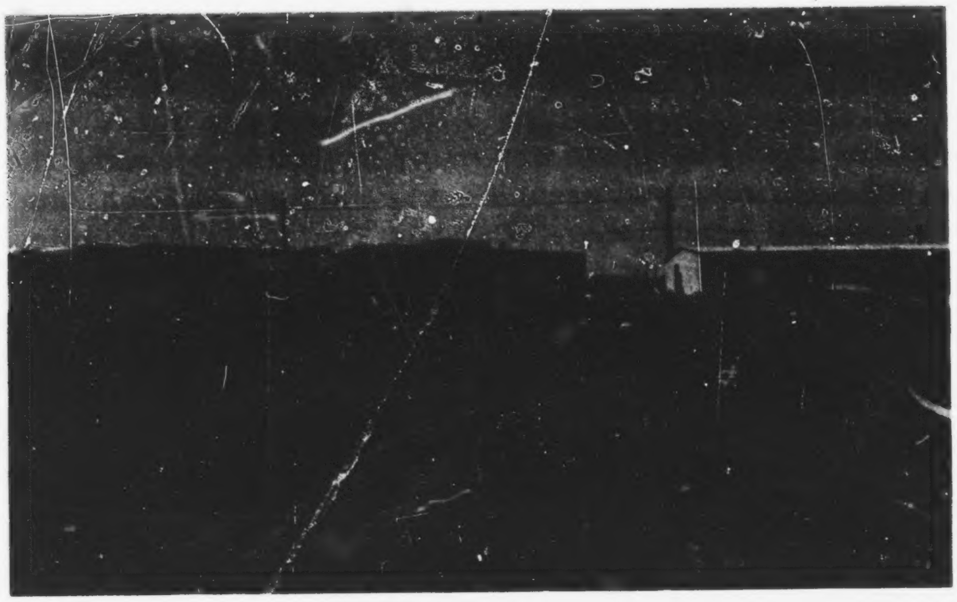

FIGURE A-1. Memorial Drive south of 41st Street looking east

TRIBUTARY TO: Mingo Creek

ZONING: U-4A Light Industrial District

This subdrainage basin is located in the upper Mingo Basin. It is a relatively new light industrial district with large amounts of undeveloped and developing land. During the testing period large amounts of land were disturbed due to the construction of a large apartment house complex. Arterial streets in the area are not curbed and guttered. Storm water runoff is mainly into unimproved drainage channels.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	13 mg/l	30 lbs./acre
COD:	110 mg/l	251 lbs./acre
Total Solids:	2242 mg/l	5107 lbs./acre

TEST AREA NO. 2

SOUTHROADS-SOUTHLAND SHOPPING CENTER AREA

FIGURE A-2. Looking northeast from southeast corner of 41st Street and Yale Avenue

TRIBUTARY TO: Joe Creek

ZONING: Predominantly U-3E General Commercial District

This drainage shed is a relatively new typical suburban commercial and retail shopping center. It is characterized by large parking lots and heavily traveled arterial streets. The estimated average daily traffic on 41st Street is 25,000 vehicles per day. The parking areas and the arterial streets are cleaned daily. All of the storm water runoff in this area is routed to covered conduits via streets and inlet structures.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	8 mg/l	27 lbs./acre
COD:	45 mg/l	150 lbs./acre
Total Solids:	275 mg/l	918 lbs./acre

TEST AREA NO. 3

SUNGATE AND WOODLAND VIEW AREA

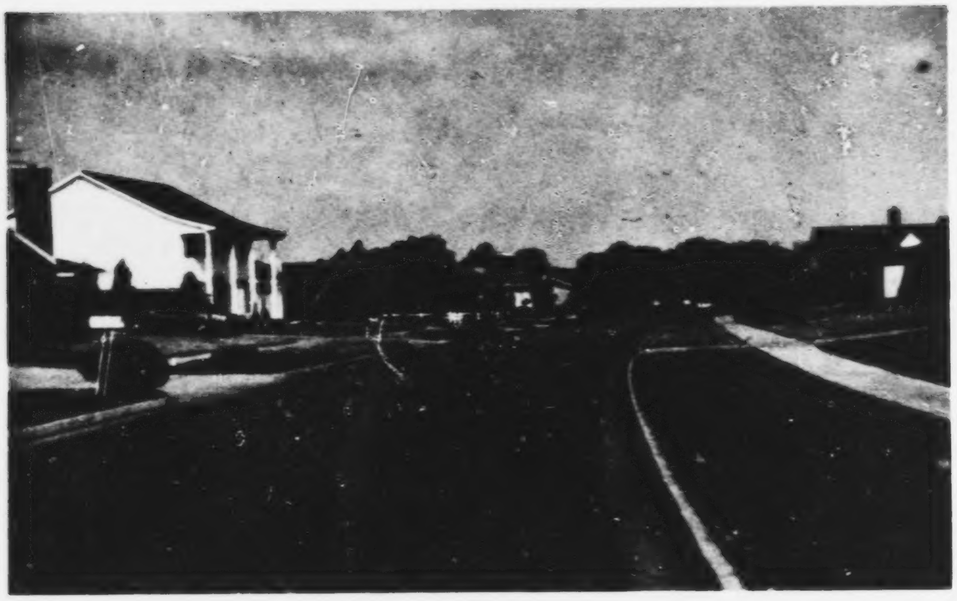

FIGURE A-3. 6700 block on East 55th Street looking east--Sungate Addition

TIRBUTARY TO: Joe Creek

ZONING: U-1C Restricted Residence District

This test area is a typical new single-family residential subdivision. No houses in this area are over 5 years old. All streets are curbed and guttered. The drainage is into an open channel that runs through the center of the addition. Two schools and a community swimming pool are also located within this drainage shed.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	8 mg/l	14 lbs./acre
COD:	65 mg/l	113 lbs./acre
Total Solids:	680 mg/l	1183 lbs./acre

TEST AREA NO. 4

SHERIDAN INDUSTRIAL DISTRICT

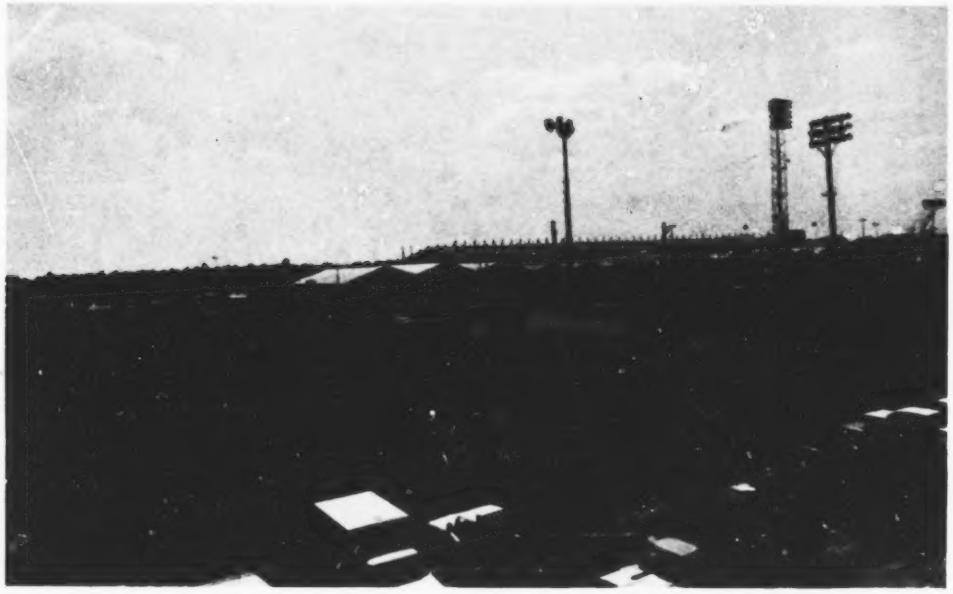

FIGURE A-4. Atop Tulsa City-County Health Department looking south over Tulsa County Fairgrounds

TRIBUTARY TO: Mingo Creek

ZONING: Predominantly U-4B Heavy Industrial District with small amount of U-1C Restricted Residence District

This test area is characterized by heavily traveled arterial streets, portions of the Tulsa County Fairgrounds, a large Sears Shopping Center, a concrete building material plant, several trucking firms, and large amounts of open storage. The drainage is into an open channel which runs through the properties of several industrial firms.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	14 mg/l	44 lbs./acre
COD:	103 mg/l	324 lbs./acre
Total Solids:	616 mg/l	1936 lbs./acre

TEST AREA NO. 5

WOODWARD PARK AREA

FIGURE A-5. Riverside Drive looking east up 26th Street

TRIBUTARY TO: Arkansas River

ZONING: Predominantly U-1C Restricted Residence District

This test area is located adjacent to the Arkansas River in a fairly old section of Tulsa. It has steep slopes and large amounts of tree cover. All of the streets are curbed and guttered. The drainage is into a large closed conduit. Located within the test area is a park.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	18 mg/l	33 lbs./acre
COD:	138 mg/l	252 lbs./acre
Total Solids:	271 mg/l	494 lbs./acre

TEST AREA NO. 6

LATIMER INDUSTRIAL DISTRICT

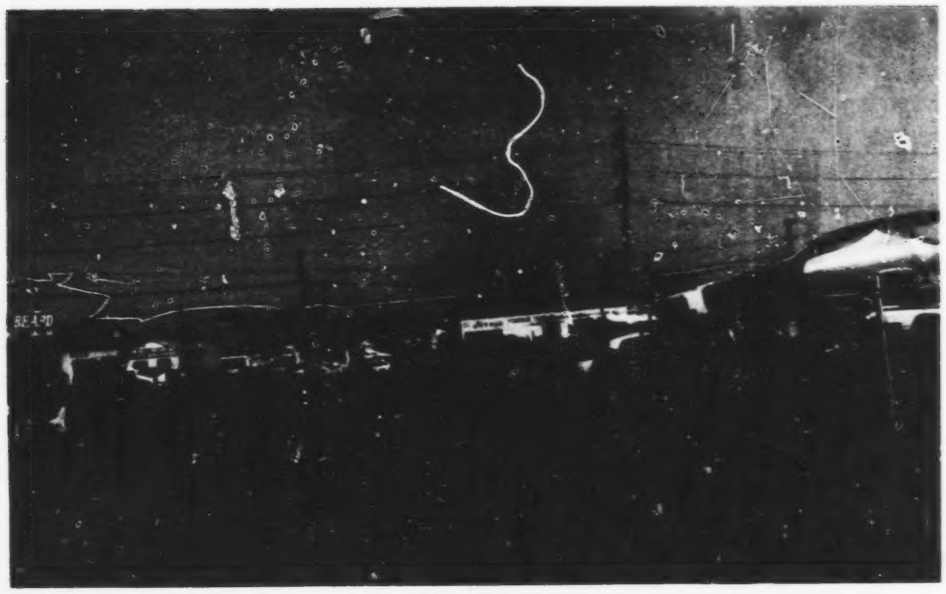

FIGURE A-6. St. Louis Avenue looking north

TRIBUTARY TO: Flat Rock Creek

ZONING: U-4B Heavy Industrial and U-1C Restricted
Residence District

This test area is a mixture of industrial firms and fair to poor residential housing. The watershed is characterized by several auto wrecking firms and trucking companies. The drainage is into a closed conduit.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	12 mg/l	21 lbs. /acre
COD:	90 mg/l	155 lbs. /acre
Total Solids:	346 mg/l	594 lbs. /acre

TEST AREA NO. 7

METHODIST MANOR

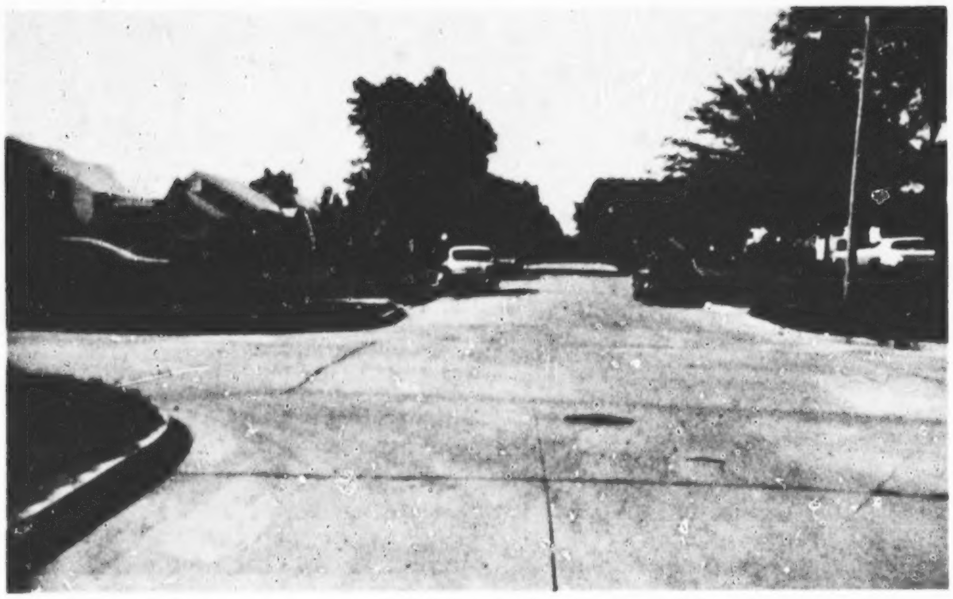

FIGURE A-7. 27th Street and Quebec Avenue

TRIBUTARY TO: Joe Creek

ZONING: U-1C Restricted Residence District

This test area is a post-World War II housing addition. Almost all homes are frame or frame and brick. The yards in the area are well-kept. Drainage is from street to inlet structures to covered drainage channel.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	8 mg/l	15 lbs./acre
COD:	48 mg/l	91 lbs./acre
Total Solids:	413 mg/l	785 lbs./acre

TEST AREA NO. 8

STRIP-PIT COLLECTION BASIN

FIGURE A-8. Virgin and Jamestown

TRIBUTARY TO: Coal Creek

ZONING: U-1C Restricted Residence District

This test area is a lower middle class postwar addition of mostly two-bedroom frame and brick houses with medium-sized tree cover. Many streets are not curbed and guttered.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	15 mg/l	33 lbs./acre
COD:	115 mg/l	252 lbs./acre
Total Solids:	382 mg/l	836 lbs./acre

TEST AREA NO. 9

SUNNY SLOPE ADDITION

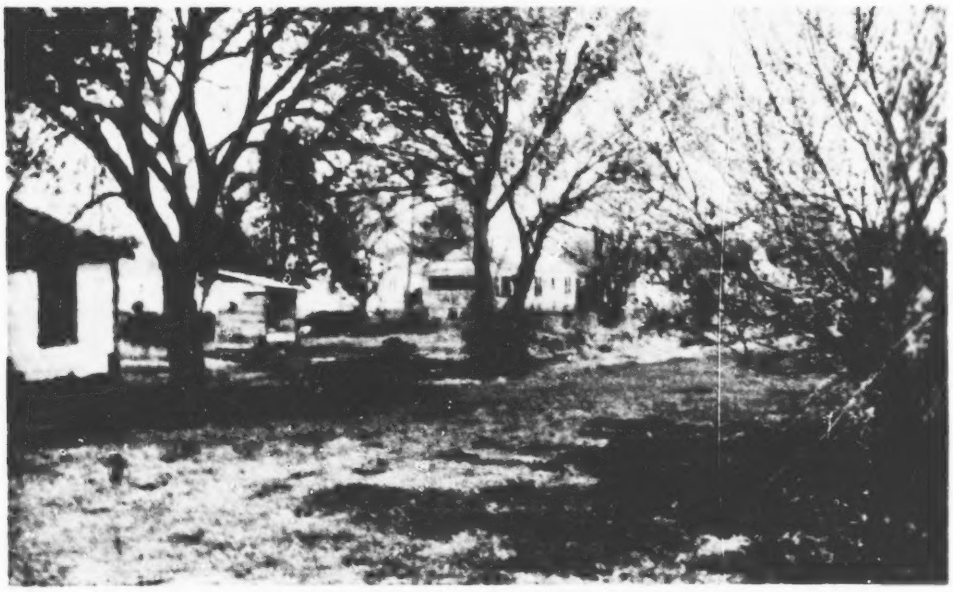

FIGURE A-9. Typical backyard in test watershed

TRIBUTARY TO: Flat Rock Creek

ZONING: U-1C Restricted Residence District

This test area is mostly composed of fairly old houses of various sizes, many nearing delapidation. All of the area is ill-kept and can be characterized by many general sanitary deficiencies, such as uncovered garbage cans, rubble, and old autos.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	10 mg/l	20 lbs./acre
COD:	117 mg/l	232 lbs./acre
Total Solids:	417 mg/l	827 lbs./acre

TEST AREA NO. 10

SOUTH CENTRAL BUSINESS DISTRICT

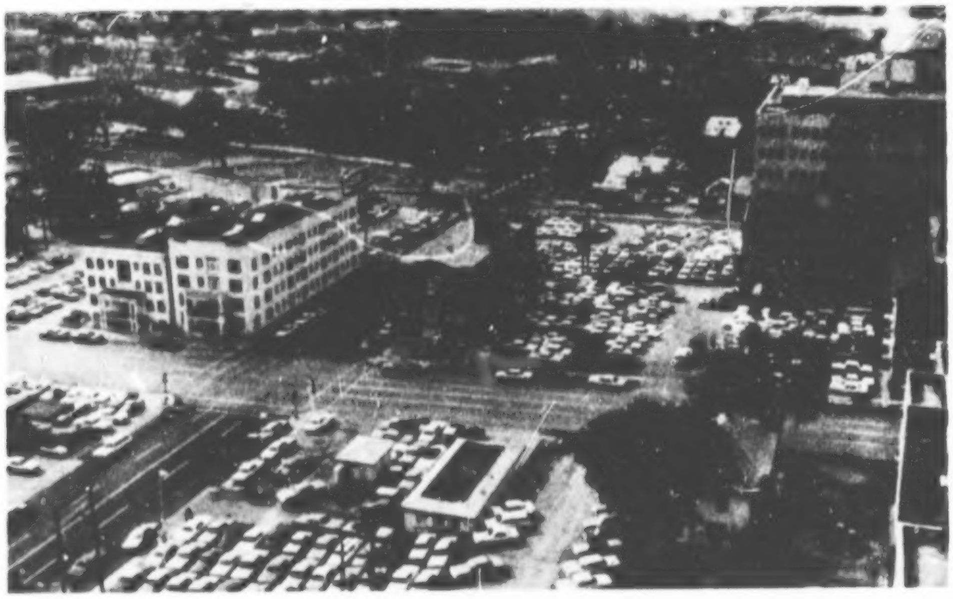

FIGURE A-10. View of parking lots and office buildings in the upper portions of the watershed

TRIBUTARY TO: Arkansas River

ZONING: Predominantly U-3DH Restricted Commercial District, some U-2A Multiple Dwelling District, some U-2B Restricted Apartment District

The upper portion of the watershed is commercial-office in nature and includes multistory buildings. The middle areas of the watershed are largely open areas with considerable tree cover; these areas have been cleared by the Tulsa Urban Renewal Authority for eventual redevelopment. Some urban renewal work is still underway in the area.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	11 mg/l	48 lbs. /acre
COD:	107 mg/l	470 lbs. /acre
Total Solids:	431 mg/l	1895 lbs. /acre

TEST AREA NO. 11

GREENWOOD DRAINAGE SHED

FIGURE A-11. Intersection of Kingston and South 18th Street

TRIBUTARY TO: Dirty Butter Creek

ZONING: U-1C Restricted Residence District
U-2A Multiple Dwelling District
U-3E General Commercial District

This test area, containing mostly small frame houses, is in the heart of Tulsa's Model City Area. The streets in the area are deteriorating, and many are not curbed and guttered. There is strip commercial activity on the arterial streets in the area.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	14 mg/l	35 lbs./acre
COD:	116 mg/l	292 lbs./acre
Total Solids:	575 mg/l	1447 lbs./acre

TEST AREA NO. 12

AIRPORT EAST

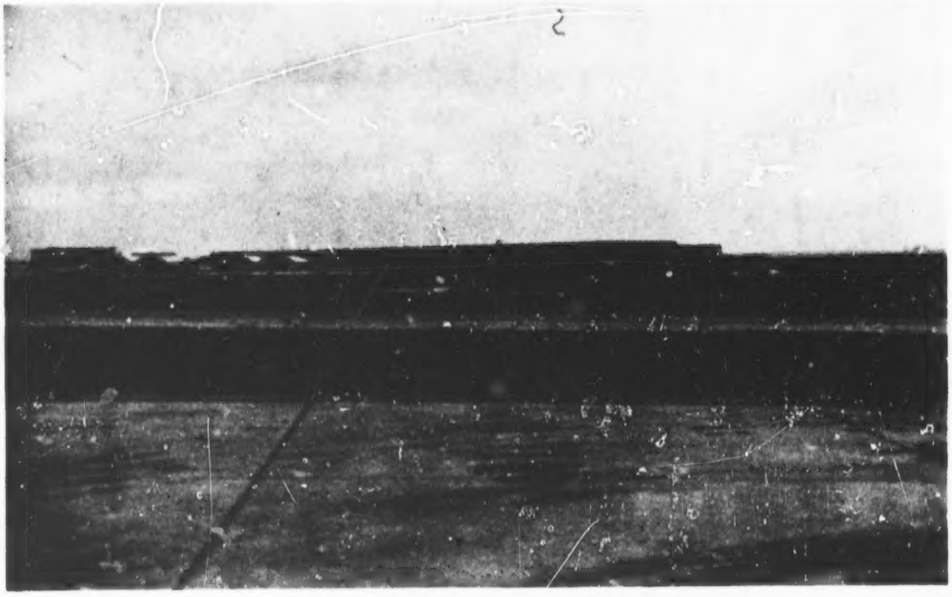

FIGURE A-12. Gilcrease Freeway looking northeast

TRIBUTARY TO: Mingo Creek

ZONING: U-4A Light Industrial District

This test area includes a portion of the Tulsa International Airport runways and supporting buildings of North American Rockwell Corporation. The drainage shed has a great amount of open grassy area. The runoff is into an unimproved open channel.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	8 mg/l	25 lbs./acre
COD:	45 mg/l	141 lbs./acre
Total Solids:	199 mg/l	625 lbs./acre

TEST AREA NO. 13

BOLEWOOD ACRES

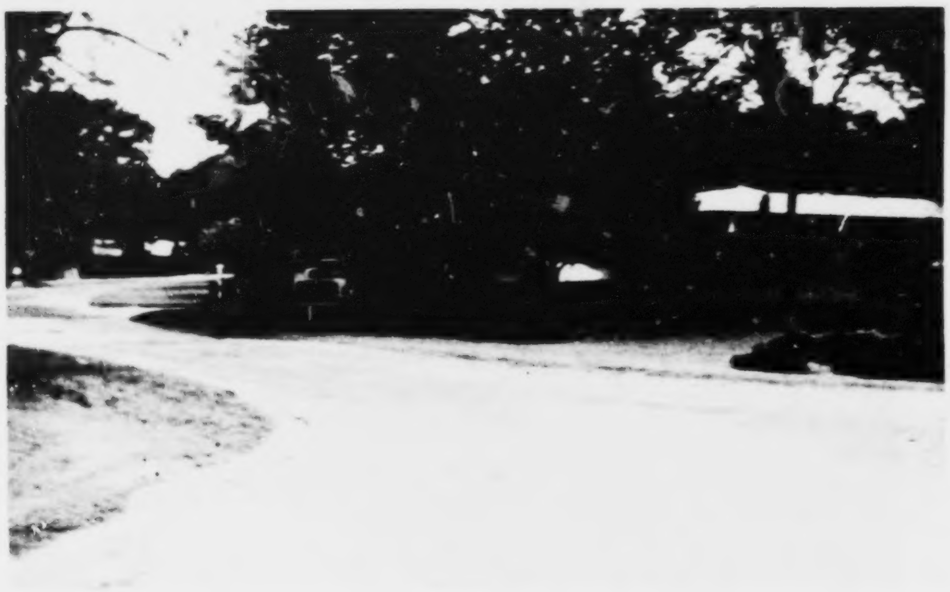

FIGURE A-13. Intersection of East 43rd Street and Oak Road

TRIBUTARY TO: Joe Creek

ZONING: U-1A Restricted Residence District

This test area is mostly a non-sewered upper-class residential area. It is characterized by large lot size, expensive homes, and a large amount of tree cover. Almost all homes have private swimming pools and individual septic systems. Most streets are not curbed and guttered. The drainage is via roadway drainage ditches.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	15 mg/l	25 lbs./acre
COD:	88 mg/l	146 lbs./acre
Total Solids:	469 mg/l	776 lbs./acre

TEST AREA NO. 14

SOUTHERN HILLS COUNTRY CLUB

FIGURE A-14. View of water hazard on the golf course

TRIBUTARY TO: Joe Creek

ZONING: Recreational

This drainage shed includes a golf course. It is characterized by tree cover, well-kept grass cover, and two small recreational ponds. The ponds capture most of the runoff water. The only time storm water runoff escapes from this watershed is during heavy rains--mostly in the spring of the year. The samples collected from this area were actually overflow from the ponds and not storm water runoff samples.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	11 mg/l	12 lbs. /acre
COD:	53 mg/l	59 lbs. /acre
Total Solids:	592 mg/l	659 lbs. /acre

TEST AREA NO. 15

ALT ADE MA PLACE

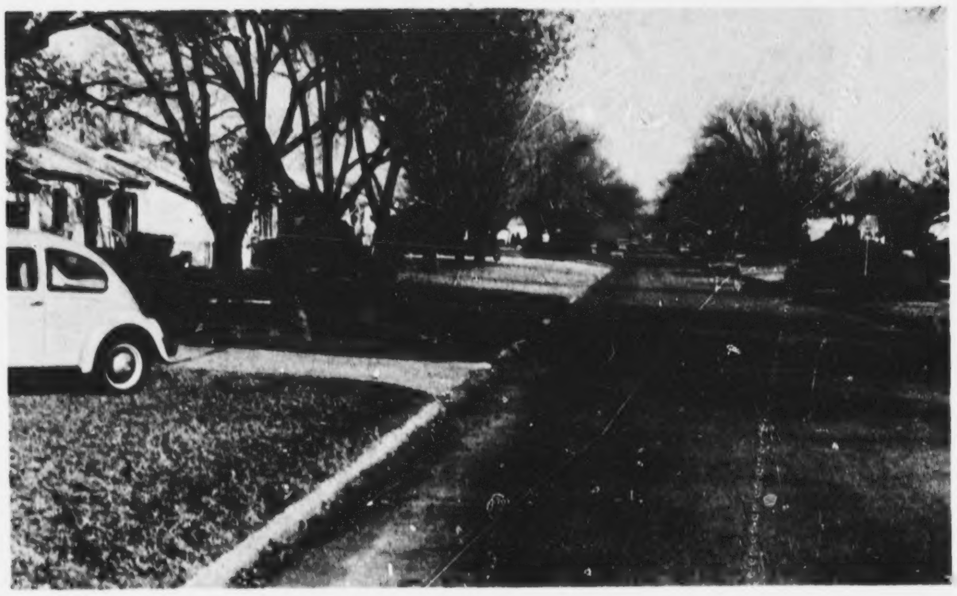

FIGURE A-15. 45th Street and Riverside Drive looking east

TRIBUTARY TO: Arkansas River

ZONING: U-1C Restricted Residence District

This residential area is a post-World War II addition of small 2-3 bedroom frame and brick houses. The area is covered with a great amount of medium sized trees. All streets are curbed and guttered.

FINDINGS:

	Average Concentration	Average Yearly Load
BOD:	12 mg/l	25 lbs./acre
COD:	42 mg/l	88 lbs./acre
Total Solids:	273 mg/l	572 lbs./acre

TABLE A-1

SUMMARY OF ZONING CLASSIFICATIONS[3]

District	Permitted Uses and Requirements
U-RE Restricted Residence District	Single family residences; lot width 120 ft.; lot area 25,000 sq. ft.; front yards 50 ft.; side yards 20 ft.; rear yards 25% of lot depth. (Board of Adjustment may approve schools, churches, and police and fire stations, subject to conditions.)
U-1A Restricted Residence District	Single family residences; lot width 100 ft.; lot area 13,500 sq. ft.; front yards 35 ft.; side yards 15 ft.; rear yards 20% of lot depth. (Schools, churches, etc., in U-RE.)
U-1B Restricted Residence District	Single family residences; lot width 75 ft.; lot area 9,000 sq. ft.; front yards 30 ft.; side yards a total of 15 ft.; neither less than 5 ft.; rear yards 20% of lot depth. (Schools, churches, etc., by Board of Adjustment.)
U-1C Restricted Residence District	Single family residences; lot width 60 ft.; lot area 7,000 sq. ft.; front yards 25 ft.; side yards 5 ft.; rear yards 20% of lot depth. (Duplexes on not less than 10,000 sq. ft. lot with Zoning Board of Adjustment approval.)
U-2A Multiple Dwelling District	Mixture of single family, duplex, multifamily, townhouse, and institutional dwelling units. Many detailed requirements including a multifamily lot area of 2,400 sq. ft. per dwelling unit.

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[3] The contents of this summary are limited and are intended to serve only as a guide. The full text of the Zoning Ordinance is in Title 42, Revised Ordinance, City of Tulsa, 1964.

TABLE A-1--Continued

District	Permitted Uses and Requirements
U-2B Restricted Apartment District	Same as U-2A except for several detailed requirements of multifamily lot area, lot width, and lot area per dwelling unit.
U-2C General Apartment District	Same as U-2A and U-2B except for several detailed requirements. Multifamily lot area per dwelling unit is 1,000 sq. ft.
U-3A Parking District	Parking of motor vehicles; single family residences. (Sign and structure limitations.)
U-3B Professional Office District	Funeral homes, offices of lawyers, architects, dentists, doctors, engineers, etc. Buildings are limited to one story or 30 ft. in height and 20% coverage of the lot. If adjacent to a U-1A through U-2C district, 10 ft. side yard is required. Signs limited to 16 sq. ft.
U-3BH Professional Office District	All U-3A and U-3B uses inclusive, plus all administrative offices of private, public, semi-public, eleemosynary, civic, religious, etc., organizations, but excluding uses where merchandise is shown or for sale on the premises. Total floor area must not exceed 50% of the lot area. Whenever a U-3BH district adjoins a U-1A through U-2A district, a setback to height ratio of 2:1 shall be in effect. When it adjoins other use districts or street rights-of-way, a ratio of 1:1 shall be in effect.
U-3C Personal Service District	Automobile service stations, ice docks, automatic vending machines for ice, milk, ice cream, or dairy products. Buildings are limited to one story in height and 30% coverage of the lot. If adjacent to residential zoning, a 10 ft. side yard is required. Also: Motels on tracts of 2-1/2 acres or more and at least 200 ft. frontage; front yard of 50 ft.; side and rear yards of 10 ft. when adjacent to residential

TABLE A-1--Continued

District	Permitted Uses and Requirements
	zoning. Dining rooms and coffee shops as accessory uses in conjunction with a motel.
U-3D Restricted Commercial District	All retail commercial uses (except those listed under U-3E and U-3F below). Note: Taverns, which were formerly allowed only in U-3E, are now included in this district, subject to the requirements of Ordinance No. 9952. Buildings limited to one story or 30 ft. in height and 50% coverage of the lot. Buildings must be set back 10 ft. from a residential district.
U-3DH Restricted Commercial District	U-3A through U-3D uses plus: All retail commercial uses except those listed in U-3E and U-3F below. Total floor or floors area must not equal more than 50% of the total lot area. When such a district adjoins a U-RE through U-2C district, the setback from such districts shall be 2 ft. for every 1 ft. in height of such building or structure. When adjoining a public street, the setback from such right-of-way line will be a distance of 1 ft. for each 1 ft. of building or structure height.
U-3E General Commercial District	All retail commercial uses and U-1A through U-2C residential uses, plus: Bowling alleys, pool halls, dance halls, taverns. Also: all general commercial uses (except those listed under U-3F below). No height or lot coverage restrictions.
U-3F Heavy Commercial District	All general commercial uses plus: bakeries, lumber yards, ice cream and dairy products manufacturing, scientific research laboratories, race tracks, miniature auto tracks, outdoor theatres, drive-in eating places. No height or lot coverage restrictions.
U-4A Light Industrial District	Light industrial or manufacturing uses. Residential uses prohibited. Buildings must be set back 150 ft. from residential districts unless a public street lies between such districts, in which case buildings shall

TABLE A-1--Continued

District	Permitted Uses and Requirements
	be set back 50 ft. Detailed specific provisions as to building height and off-street parking.
U-4B Heavy Industrial District	Heavy industrial uses. Residential use prohibited. Building setback lines equivalent to U-4A above; no height restriction; specific detailed provisions for off-street parking.
U-5 Unrestricted District	Any lawful use, except that residential uses are prohibited. Building setback requirements equivalent to U-4A above; no height restriction; specific detailed provisions for off-street parking.

APPENDIX B

SOURCES OF STORM WATER POLLUTION

This appendix describes with pictures several sources of storm water pollution. The pictures were taken in various areas of the City of Tulsa, Oklahoma. Each one of these sources can be corrected by better public works practices and by enforcing existing or new local ordinances pertaining to general sanitary conditions.

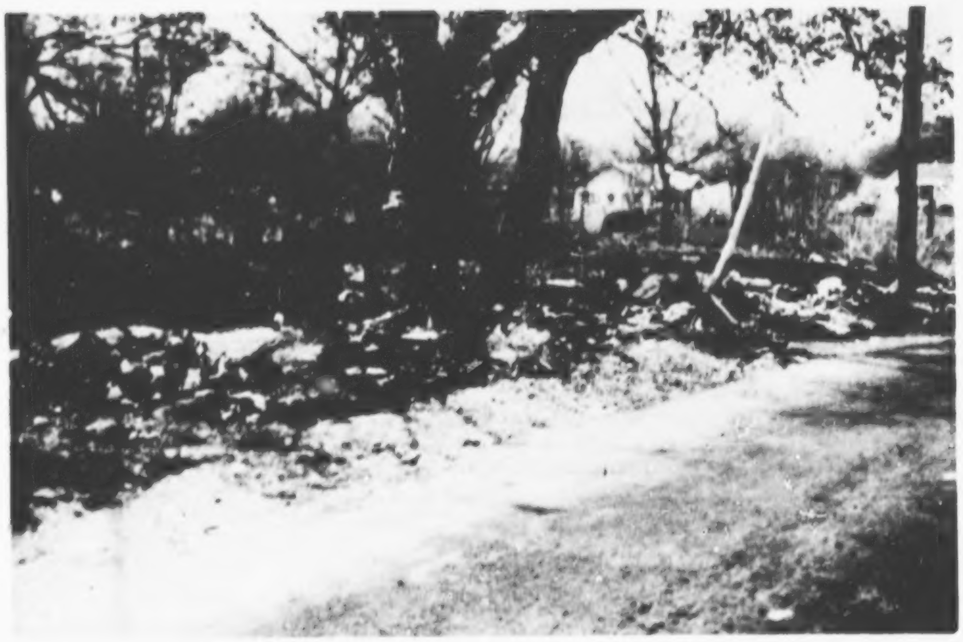


FIGURE B-1. Indiscriminate roadside dumping of trash and rubble

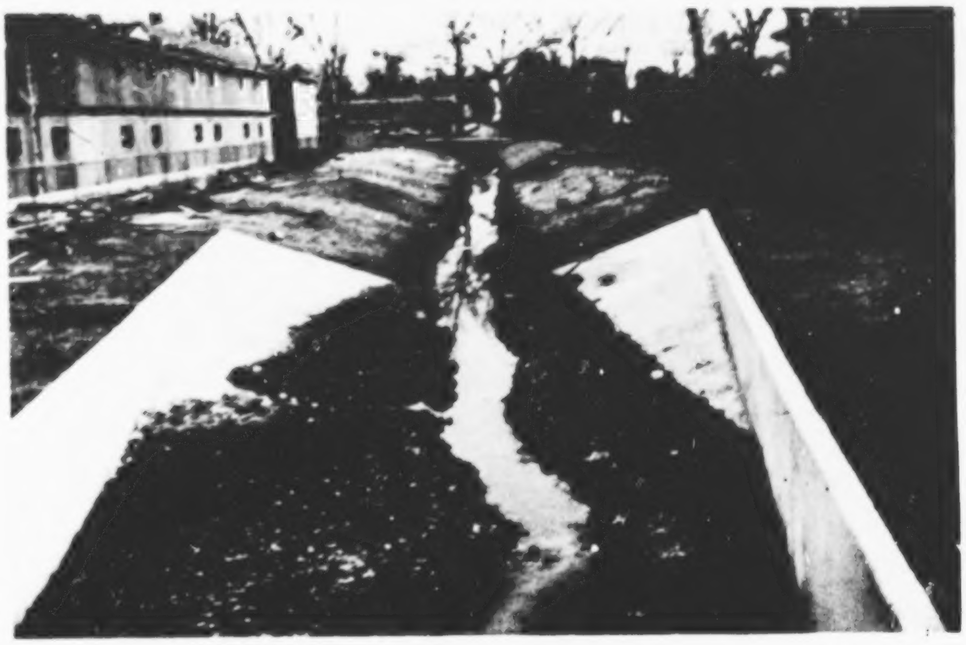


FIGURE B-2. Scattering of waste construction material and poor maintenance of drainage channel

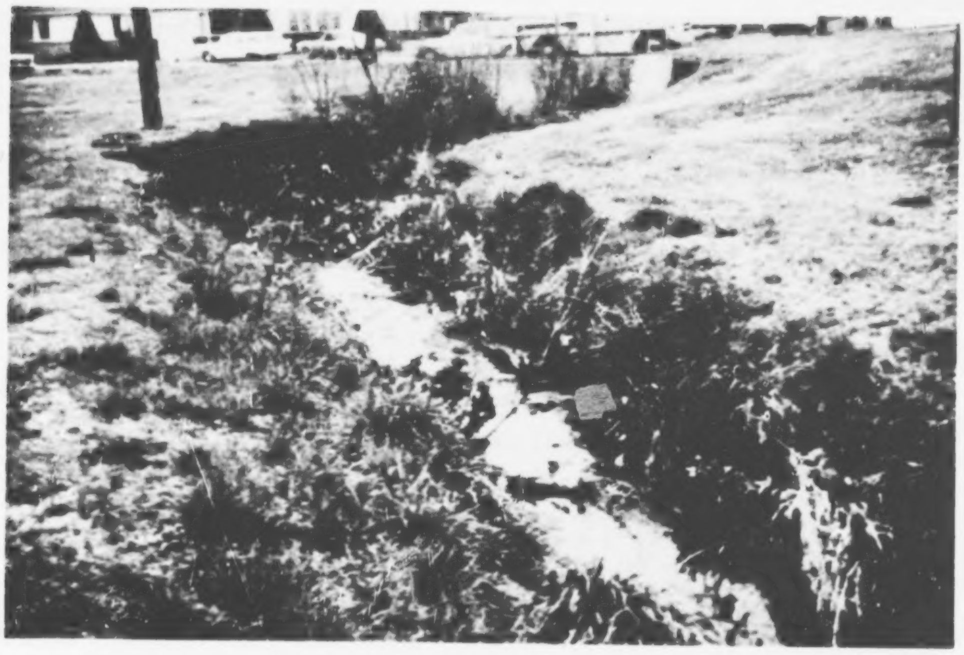


FIGURE B-3. Unimproved and poorly maintained open drainage channel

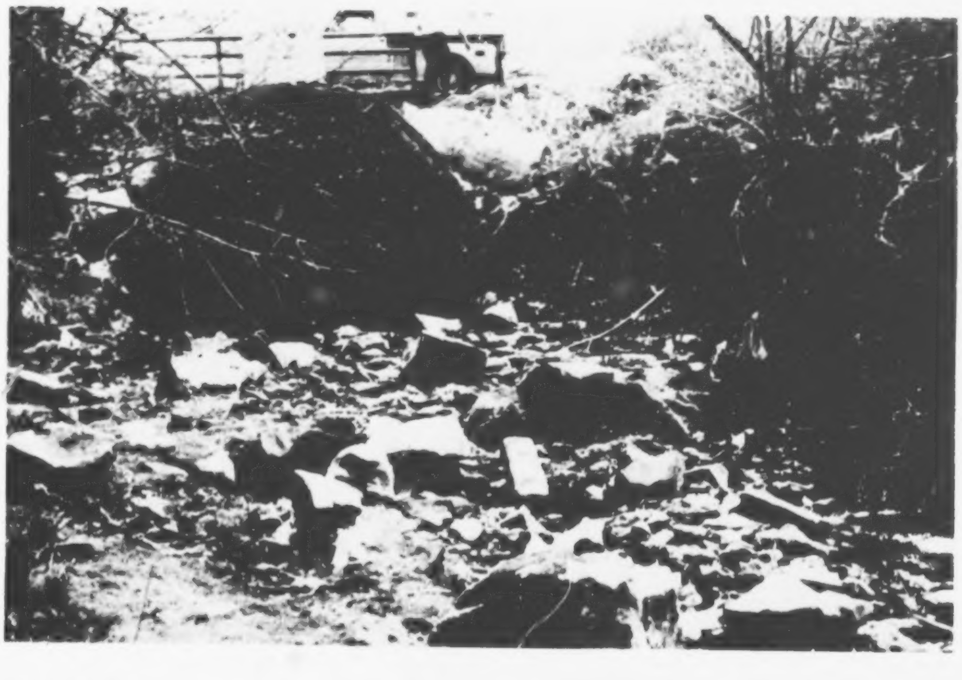


FIGURE B-4. Indiscriminate dumping into open drainage channel

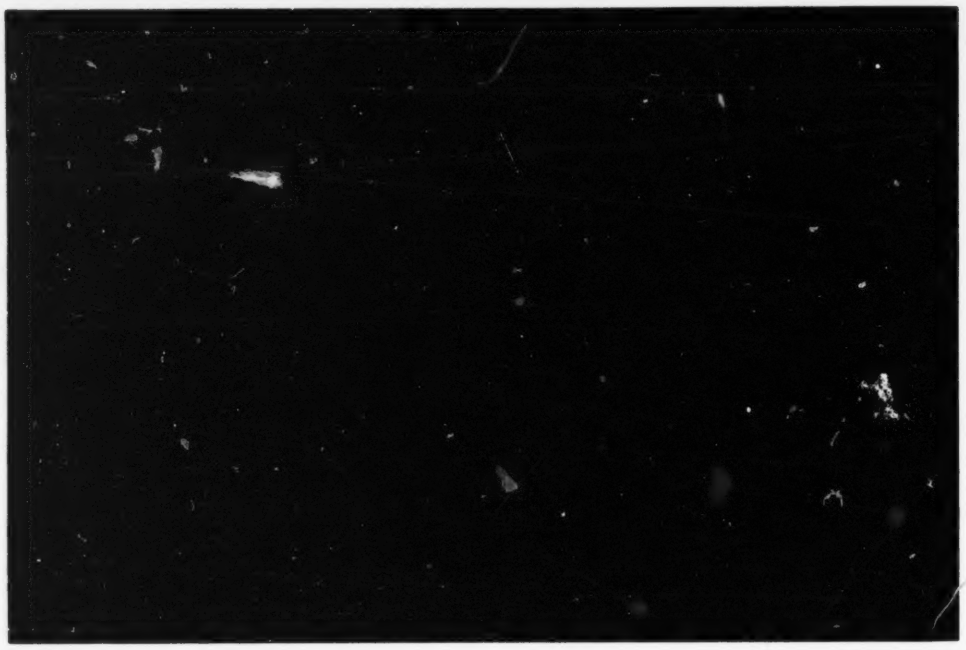


FIGURE B-5. Indiscriminate dumping into open drainage channel (grass trimmings)

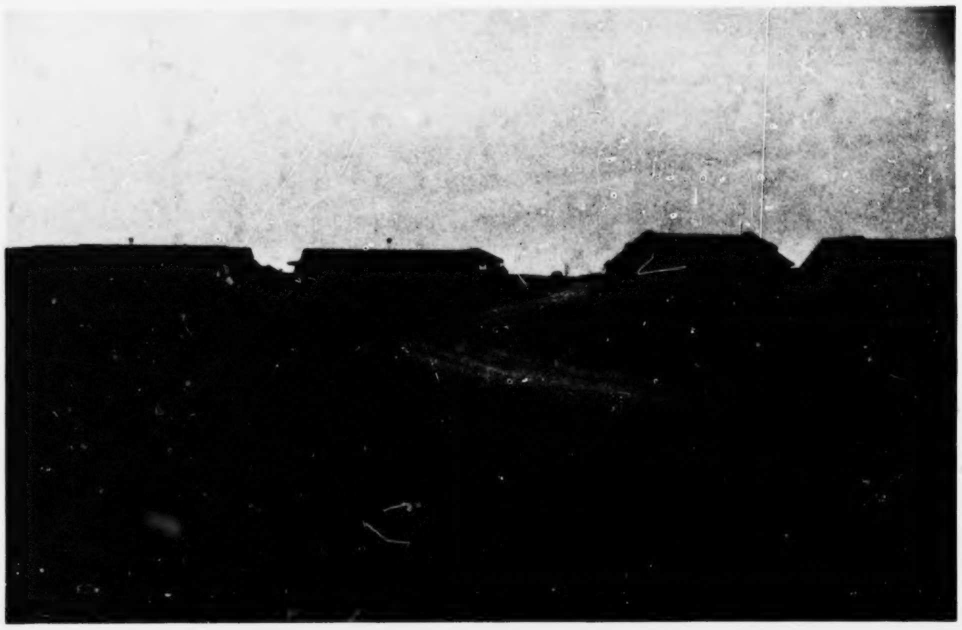


FIGURE B-6. Poorly maintained drainage structure--buildup of decaying organic matter resulting in flow stoppage

FIGURE B-7. Vast area of disturbed land with ground cover removed and open storage of material during construction activities

FIGURE B-8. Dirty streets--subdivision development

FIGURE B-9. Land filling with construction material waste adjacent to open drainage channel

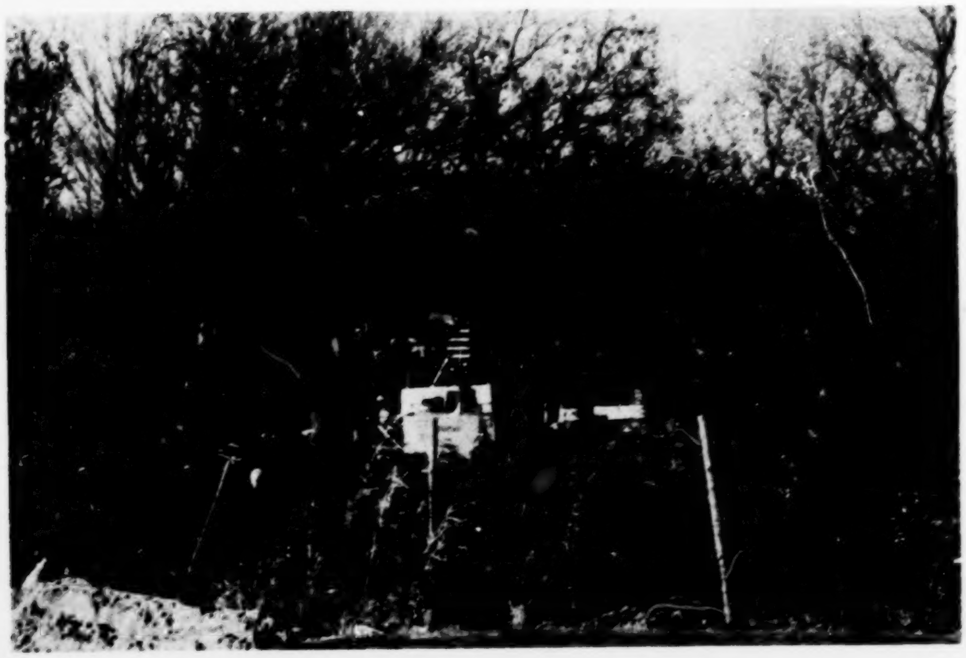


FIGURE B-10. Residential parcel deficiencies--uncovered garbage cans and piles of rubble

APPENDIX C

TULSA METROPOLITAN PLANNING DATA AND INFORMATION SYSTEM: LAND ACTIVITY FILE

The Tulsa Metropolitan Area Planning Commission's (TMAPC) "metropolitan data bank concept" originated from the need for improved methods of recording urban data to be used by governmental agencies. With the capabilities of the new computers, it is possible to economically store, maintain, manipulate, and retrieve considerable amounts of data. The following is a short description of TMAPC's data bank and operating procedure.

TMAPC has developed three distinct data processing systems in the last ten years. The first, called "A Program for Automatic Tabulation of Basic Data for the Tulsa Metropolitan Area," was initiated in 1958. The second system, established in 1965, was the "Tulsa Metropolitan Data Center System," a product of the Metropolitan Data Center Project. The third system, initiated in 1966 and presently in use, is the "Metropolitan Planning Data and Information System: Land Activity File."

The operation of the first two data processing systems will not be discussed here; only the current "Land Activity File" will be considered.

Land Activity File Operation

The TMAPC's Land Activity File Operation is based on electronic data processing equipment which employs magnetic tape for the storage and processing of current data needed in urban planning activities. Following is a summary of the operation of the Land Activity File in terms of data file storage, file development, and file usage.

Data File Storage - The Land Activity File presently consists of three large reels of magnetic tape containing land use data. These data represent approximately 150,000 parcel records covering an area of about 577 square miles.

Equipment and Records - At present, the TMAPC utilizes the data processing equipment of the City of Tulsa. Tulsa has an IBM 360 Computer which requires magnetic tapes for data file storage.

Magnetic tape drives do not have the direct-file access capabilities of disk storage drives, but are extremely flexible in that they have very few data storage requirements or file layout restrictions.

A printed documentary record of the data file contents, called the Master File Card Reference System, is maintained. The card reference system consists of approximately 150,000 preprinted cards grouped by township section and range, census tract, planning block, and planning parcel. These reference cards allow for easy handling as well as quick access to the file contents.

Having the reference file on punch cards instead of on a tabulated listing provides up-to-date reference without the need to reprint the entire data set every year. The entire file is reprinted only when a substantial change in the format occurs, as when new items are collected, old items deleted, or data files combined.

Data File Design - Data items are grouped in a logical organization called the "Parcel Record Format," shown on the following two pages, to accomodate processing of the data by the computer. This grouping makes possible the systematic collection and recording of physical, social, and economic data about each parcel. The parcel number code is used as the common file reference code which serves to properly identify and locate land activity. The data file is organized in ascending sequential parcel number order, and categorizes planning data of every parcel into three basic information levels: (1) parcel information, (2) building and/or open space information, and (3) establishment information.

Parcel information includes the location, characteristics, use data, and zoning data associated with a specific parcel. Examples of this information level are the building condition and gross floor area. Each parcel record includes a numeric file identification code for individual and multiple buildings and/or open space uses (open parking lots or tennis courts). Establishment characteristics, such as floor space utilized and the establishment activity code, are recorded at the establishment information level. Each parcel record provides for multiple establishments within a building or open space classification. A numeric file identification code is assigned to each establishment. Establishment characteristics are recorded separately for every establishment in the file. Multifamily housing units are summarized for each structure. All parcel records entered into the data file require a parcel identification number, building location number, and establishment location number.

TMAPC LAND ACTIVITY FILE
PARCEL RECORD FORMAT

I. Parcel Information

- A. Parcel location information
    - Parcel identification number
    - Grid coordinates
    - Parcel address
- B. Political jurisdictions
    - County
    - Incorporated unit code
- C. Planning/statistical areas
    - Community statistical area code
    - Planning statistical area number
    - Industrial planning district code
    - Commercial area code
    - Community renewal project number
    - Transportation sub-zone number
    - Postal zone number
    - Street control section number
    - Land use map number

II. Parcel Characteristics

- A. Size
    - Parcel area
    - Average parcel width
    - Average parcel depth
    - Parcel frontage
- B. Tax and economic factors
    - Assessed land value
    - Assessed improvements value
    - Assessed total value
    - Parcel sale data
    - Parcel sale price
    - Homestead exemption
- C. Other Characteristics
    - Area building practice
    - Area environmental status ownership

TMAPC LAND ACTIVITY FILE
PARCEL RECORD FORMAT--Continued

III. Parcel Use Data
  - Free off-street parking spaces
  - Comprehensive plan use code
  - Predominant use group code

IV. Zoning Data
  - Zoning classification code

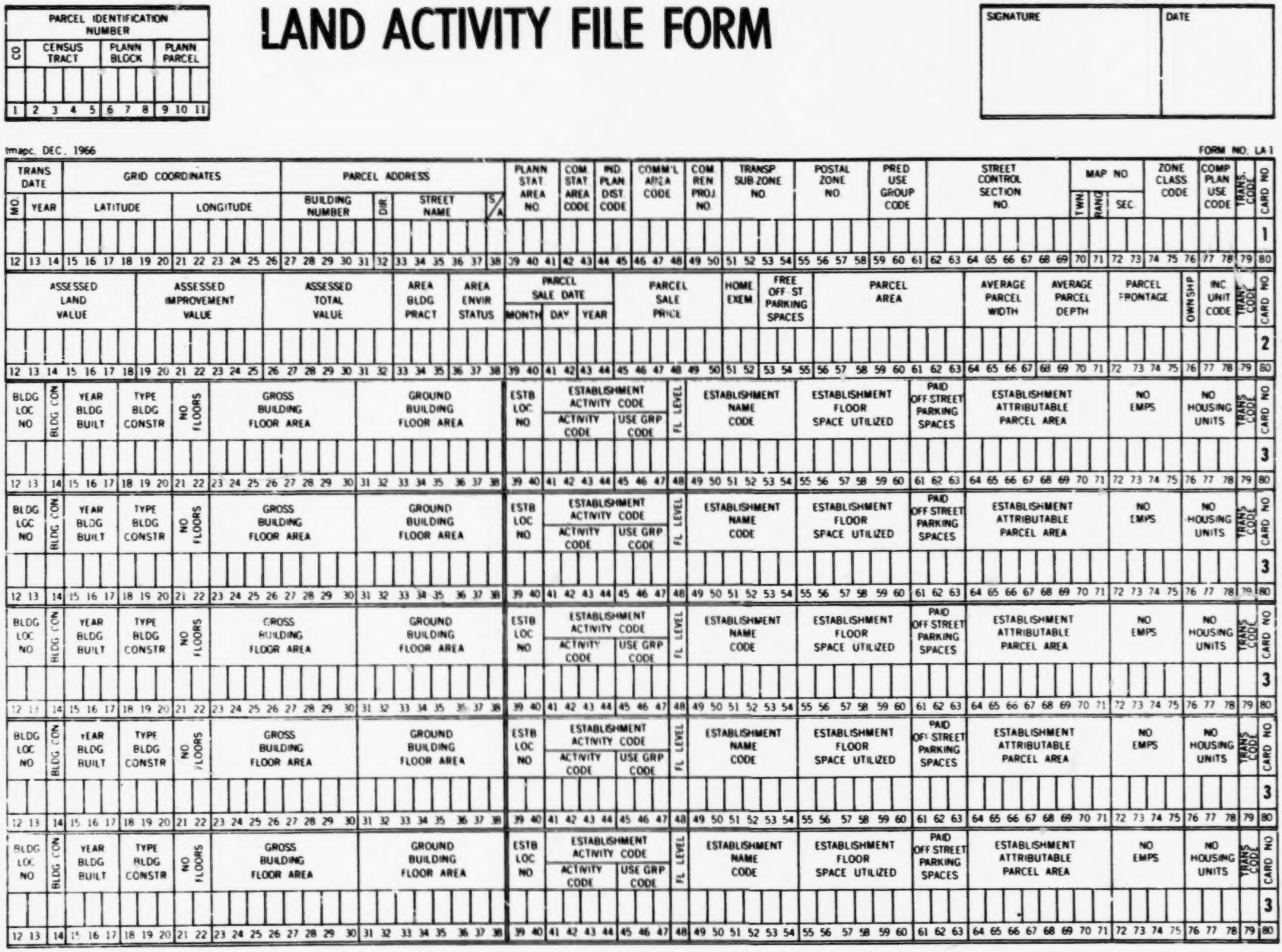
V. Building Information

  A. General building data
    - Building location number
    - Building condition
    - Year building built
    - Type of building construction

  B. Building Floor Data
    - Number of floors
    - Gross building floor area
    - Ground building floor area

VI. Establishment Information
  - Establishment location code
  - Floor level
  - Establishment name code
  - Establishment floor space utilized
  - Paid off-street parking spaces
  - Establishment attributable parcel area
  - Number of employees
  - Number of housing units

Data File Format - The "Land Activity File Form," Figure C-1, contains 47 separate classifications: 31 parcel items, 7 building items, and 9 establishment items. These data are contained within three 80-column cards numbered 1, 2, and 3. Cards 1 and 2 contain only parcel data items. The number 3 card includes both building information and establishment information. The card control number appears in column 80 of each card on the form. Card control number 3 appears five times on the activity form. Therefore, a single form accommodates a total of five separate buildings and establishments or any



PARCEL IDENTIFICATION NUMBER			
CO	CENSUS TRACT	PLANN BLOCK	PLANN PARCEL
1	2 3 4 5	6 7 8	9 10 11

LAND ACTIVITY FILE FORM

SIGNATURE	DATE

tmapc. DEC. 1966

FORM NO. LA 1

TRANS DATE		GRID COORDINATES		PARCEL ADDRESS				PLANN STAT AREA NO	COM STAT AREA CODE	IND PLAN DIST CODE	COMM'L AREA CODE	COM REN PROJ NO	TRANSP SUB ZONE NO	POSTAL ZONE NO	PRED USE GROUP CODE	STREET CONTROL SECTION NO	MAP NO			ZONE CLASS CODE	COMP PLAN USE CODE	TRANS. CODE	CARD NO
MO	YEAR	LATITUDE	LONGITUDE	BUILDING NUMBER	DIR	STREET NAME	S/A										TWN	RANG	SEC				
																							1
12	13 14	15 16 17 18 19 20	21 22 23 24 25 26	27 28 29 30 31	32	33 34 35 36 37	38	39 40 41	42 43	44 45	46 47 48	49 50	51 52 53 54	55 56 57 58	59 60 61	62 63 64 65 66 67 68 69	70	71	72 73	74 75 76	77 78	79	80

ASSESSED LAND VALUE	ASSESSED IMPROVEMENT VALUE	ASSESSED TOTAL VALUE	AREA BLDG PRACT	AREA ENVIR STATUS	PARCEL SALE DATE			PARCEL SALE PRICE	HOME EXEM	FREE OFF-ST PARKING SPACES	PARCEL AREA	AVERAGE PARCEL WIDTH	AVERAGE PARCEL DEPTH	PARCEL FRONTAGE	OWNSHP	INC UNIT CODE	TRANS. CODE	CARD NO
					MONTH	DAY	YEAR											
																		2
12 13 14 15 16 17 18	19 20 21 22 23 24 25	26 27 28 29 30 31 32	33 34 35	36 37 38	39 40	41 42	43 44	45 46 47 48 49 50	51 52	53 54 55	56 57 58 59 60 61 62 63	64 65 66 67	68 69 70 71	72 73 74 75	76	77 78	79	80

BLDG LOC NO	BLDG CON	YEAR BLDG BUILT	TYPE BLDG CONSTR	NO FLOORS	GROSS BUILDING FLOOR AREA	GROUND BUILDING FLOOR AREA	ESTB LOC NO	ESTABLISHMENT ACTIVITY CODE		FL LEVEL	ESTABLISHMENT NAME CODE	ESTABLISHMENT FLOOR SPACE UTILIZED	PAID OFF STREET PARKING SPACES	ESTABLISHMENT ATTRIBUTABLE PARCEL AREA	NO EMPS	NO HOUSING UNITS	TRANS. CODE	CARD NO
								ACTIVITY CODE	USE GRP CODE									
																		3
12 13	14	15 16 17	18 19 20	21 22	23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38	39 40	41 42 43 44	45 46 47	48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63	64 65 66 67 68 69 70 71	72 73 74 75	76 77 78	79	80

BLDG LOC NO	BLDG CON	YEAR BLDG BUILT	TYPE BLDG CONSTR	NO FLOORS	GROSS BUILDING FLOOR AREA	GROUND BUILDING FLOOR AREA	ESTB LOC NO	ESTABLISHMENT ACTIVITY CODE		FL LEVEL	ESTABLISHMENT NAME CODE	ESTABLISHMENT FLOOR SPACE UTILIZED	PAID OFF STREET PARKING SPACES	ESTABLISHMENT ATTRIBUTABLE PARCEL AREA	NO EMPS	NO HOUSING UNITS	TRANS. CODE	CARD NO
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12 13	14	15 16 17	18 19 20	21 22	23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38	39 40	41 42 43 44	45 46 47	48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63	64 65 66 67 68 69 70 71	72 73 74 75	76 77 78	79	80

BLDG LOC NO	BLDG CON	YEAR BLDG BUILT	TYPE BLDG CONSTR	NO FLOORS	GROSS BUILDING FLOOR AREA	GROUND BUILDING FLOOR AREA	ESTB LOC NO	ESTABLISHMENT ACTIVITY CODE		FL LEVEL	ESTABLISHMENT NAME CODE	ESTABLISHMENT FLOOR SPACE UTILIZED	PAID OFF STREET PARKING SPACES	ESTABLISHMENT ATTRIBUTABLE PARCEL AREA	NO EMPS	NO HOUSING UNITS	TRANS. CODE	CARD NO
								ACTIVITY CODE	USE GRP CODE									
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BLDG LOC NO	BLDG CON	YEAR BLDG BUILT	TYPE BLDG CONSTR	NO FLOORS	GROSS BUILDING FLOOR AREA	GROUND BUILDING FLOOR AREA	ESTB LOC NO	ESTABLISHMENT ACTIVITY CODE		FL LEVEL	ESTABLISHMENT NAME CODE	ESTABLISHMENT FLOOR SPACE UTILIZED	PAID OFF STREET PARKING SPACES	ESTABLISHMENT ATTRIBUTABLE PARCEL AREA	NO EMPS	NO HOUSING UNITS	TRANS. CODE	CARD NO
								ACTIVITY CODE	USE GRP CODE									
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12 13	14	15 16 17	18 19 20	21 22	23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38	39 40	41 42 43 44	45 46 47	48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63	64 65 66 67 68 69 70 71	72 73 74 75	76 77 78	79	80

BLDG LOC NO	BLDG CON	YEAR BLDG BUILT	TYPE BLDG CONSTR	NO FLOORS	GROSS BUILDING FLOOR AREA	GROUND BUILDING FLOOR AREA	ESTB LOC NO	ESTABLISHMENT ACTIVITY CODE		FL LEVEL	ESTABLISHMENT NAME CODE	ESTABLISHMENT FLOOR SPACE UTILIZED	PAID OFF STREET PARKING SPACES	ESTABLISHMENT ATTRIBUTABLE PARCEL AREA	NO EMPS	NO HOUSING UNITS	TRANS. CODE	CARD NO
								ACTIVITY CODE	USE GRP CODE									
																		3
12 13	14	15 16 17	18 19 20	21 22	23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38	39 40	41 42 43 44	45 46 47	48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63	64 65 66 67 68 69 70 71	72 73 74 75	76 77 78	79	80

FIGURE C-1
LAND ACTIVITY FILE FORM

combination of buildings and establishments totaling five.

The first 11 columns of every card are for the parcel identification number, which serves as the common reference number for related information concerning each parcel. Column 79 of each card is used for the file transaction code data field.

Every record in the file contains 160 card columns of information characterizing each parcel and its location, political jurisdiction, planning/statistical areas, size, tax and economic factors, parcel use data, zoning data, and other characteristics. Thirty-eight columns describe each building and its location, general building data, and building floor data. Forty columns describe each establishment, its location, and establishment characteristics.

APPENDIX D

ADMINISTRATIVE AND LEGAL CONTROL
OF
WATER POLLUTION
IN THE
STATE OF OKLAHOMA
AND
THE CITY OF TULSA

The following pages include a brief description of the structure of pollution control in the State of Oklahoma and pertinent provisions of Tulsa's ordinances which were assembled and analyzed in the course of this study. It should be noted that almost all of the City of Tulsa's ordinances indirectly regulate or control storm water pollution. The enforcing power is also spread over several different city departments.

State of Oklahoma

The Oklahoma Legislature enacted House Bill 905 in 1968, creating the Department of Pollution Control. This department is administered by a Pollution Control Coordinating Board composed of the heads of five state agencies, each of which has statutory authority. The five agencies are the State Water Resources Board, State Corporation Commission, State Department of Health, State Department of Agriculture, and State Department of Wildlife Conservation.

The Department of Pollution Control is responsible for establishing a coordinated water pollution control program, utilizing the existing resources and facilities in the five state agencies having water pollution control responsibilities and authority under existing statutes.

The powers and duties of the board are:

1. To coordinate and eliminate duplication of effort by the State agencies having statutory authority in water pollution control.

2. To request member agencies to investigate suspected or potential pollution and to file a report on such investigations with the Pollution Control Coordinating Board.

3. To conduct studies, investigation, research, and demonstrations for the prevention and control of pollution.

4. To assume jurisdiction in a pollution problem if the agency having statutory jurisdiction fails to meet its responsibility in regard to that problem.

5. To establish, amend, or repeal standards for quality of the waters of the state.

6. To hold hearings, issue notices, and issue subpoenas for the attendance of witnesses and for the production of documents in the enforcement and administration of the Water Pollution Control Act.

Each agency has its own area of responsibility in Water Pollution Control. Below is a brief resume of these responsibilities.

State Department of Agriculture -Responsible for enforcing pesticide applicator laws to prevent water pollution by pesticides. Commercial applicators are required to be licensed, bonded, and responsible for any damages caused by their operations. Owners of livestock feed yards are licensed and are required to provide such facilities and to take such action as may be necessary to avoid any water pollution which might result from their operations.

State Corporation Commission -Makes and enforces rules governing the handling, storage, and disposition of mineral brines, waste, oil, and other deleterious substances related to the drilling, development, production, refining, and processing of oil and gas products.

State Department of Health -Responsible for the prevention, control, and abatement of water pollution associated with discharge and nuisance problems. The State Department of Health is also responsible for reservoir sanitation and the sanitation and healthfulness of public water supplies and public bathing places.

State Water Resources Board -Responsible for pollution control as it applies to industry with the exception of waste water discharges from the oil and gas industry. All other industries are subject to the rules and regulations of the Water Resources Board regarding pollution control.

State Department of Wildlife Conservation -Charged with the conservation of all wildlife resources in the state. Any time that lime, sawdust, salt water, crude oil (oil pollution must first be reported to the Corporation Commission), explosives, drugs, or other deleterious substances pollute water to the extent that wildlife suffers, the State Department of Wildlife Conservation acts to correct the problem.

City of Tulsa

The City of Tulsa has many local ordinances that indirectly regulate or control storm water pollution. These ordinances are administered by several different city departments, each department having its own area of responsibility. Below are all the ordinances that were found in the Charter and Revised Ordinances of the City of Tulsa, Oklahoma, which, although primarily designed for other reasons, indirectly reduce or control storm water pollution.

Charter of the City of Tulsa and Amendments Thereto
Article II. Powers of the City
Section 5. HEALTH

(5) The City of Tulsa is hereby given full power and authority to take such steps to improve and preserve the purity of the water in Arkansas River, above the city of Tulsa, as it may think necessary; provided, that the power in this section shall not be construed to give said corporation any jurisdiction or control over said river beyond the corporate limits of said city, except for the purpose of protecting or improving the water shed, i.e., and water supply of both Arkansas River and the smaller streams or tributaries; provided further, that the said corporation shall have the right to condemn land, buildings and outhouses or closets when it may deem the same necessary for the protection and preservation of the purity of the water in said river, and shall have power to control the same.

The City of Tulsa shall also have power to require any persons or corporations owning or operating manufacturing enterprises within or without the city which shall discharge refuse matter into Arkansas River or its tributaries, to make other provisions for such refuse matter or so purify the same as that the public health will be fully protected.

Title 11 - Engineering Department
Chapter 9. Construction on or over Easements

Section 121. CONSTRUCTION PERMITTED OVER STORM SEWER EASEMENTS

(121) The construction of buildings, and/or structures over, upon, and in easements of land for storm sewer purposes, inuring to the benefit of the City of Tulsa and inuring to the benefit of the "public" shall hereafter be permitted within the City of Tulsa over, upon and in said easement lands. (Ord. No. 10913)

Section 122. PERMIT REQUIRED

Any person desiring to construct a building and/or structure over, upon, or in a storm sewer easement, or a portion thereof, shall obtain, prior thereto, a permit from the office of the City Engineer of the City of Tulsa, Oklahoma, therefore, the issuance of which shall be the condition precedent to such construction. (Ord. No. 10913)

Section 123. AGREEMENT REQUIRED

Any person desiring to construct a building or structure upon a storm sewer easement inuring to the benefit of the City of Tulsa and located within the City limits of the City of Tulsa, Oklahoma, shall execute an agreement with the City of Tulsa subject to approval thereof by the City Engineer, setting forth such terms, conditions and provisions as may be prescribed by the City Engineer to whom authority is hereby delegated to execute said agreement in behalf of the City of Tulsa. Such agreement shall be in writing and shall restrict the use of said storm sewer easement substantially in accordance with the restrictions and conditions as herein below set forth, and said agreement shall, upon execution, be recorded in the office of the County Clerk of the County in which that property is located, recording cost to be paid by the property owner. (Ord. No. 10913)

Title 17 - Health Regulations
Chapter 18

Section 415. UNSANITARY CONDITIONS.

It shall be unlawful and a public nuisance for any person to suffer, permit, or have upon their premises, whether owned or occupied by them either one or more of the following unsanitary fly-producing or mosquito-producing, disease-causing conditions, any of which is hereby declared to be a nuisance, to-wit:

(a) Manure which is not securely protected from flies and mosquitoes.

(b) Garbage which is not securely protected from flies and mosquitoes.

(c) Vegetable waste, grass sod, moulded grass, trash, litter, rags, or refuse of any kind, nature, description or composition in which flies or mosquitoes may breed or multiply.

(d) Standing water, either in low places or vessels. Provided that all low places, pits, depressions, sloughs, ditches, sags, or basins in which water naturally collects from rain or natural drainage or overflow or backwater shall be drained in such a manner that such water shall fall in the water channels into which such places naturally drain, provided that water may be kept in clean vessels for the purpose of watering fowls or animals on conditions that the same is emptied each day and cleaned thoroughly of all accumulation each day.
It shall be the duty of the Director of Health to prevent and abate all nuisances as described in this chapter in the manner prescribed by law.

Title 27 - Penal Code
Chapter 6. Public Property
Section 91. PROTECTION OF PUBLIC PROPERTY

It is hereby declared to be unlawful and an offense for any person in the City of Tulsa, Oklahoma, to do any of the following things, upon any public street, highway, avenue, alley, public place or upon any property belonging to the City of Tulsa, regardless of the purpose for which such property was dedicated, acquired or purchased, without the consent of the Board of Commissioners of said city, to-wit:

(f) To dump boxes, trash, litter, paper, refuse matter in cans, garbage, or any other articles in any substantial quantities upon any of the public property of said City.

Chapter 24. Streets and Sidewalks

Section 286. STAGNANT WATER

All owners or occupants of any grounds within the City are forbidden to suffer stagnant water to stand or remain on any of the said premises; all such stagnant water is hereby declared to be a public nuisance and the owners, lessees, or occupants of such grounds are required, whenever the Board of Commissioners shall deem it necessary, to cause said grounds to be leveled or to be drained so that stagnant water be allowed to flow naturally and freely from said place. (Ord. No. 499)

Section 353. CLEANING

It shall be unlawful for any person to omit or refuse to clean off the sidewalk and gutter in front of the premises of such person or the alley in the rear of such premises when notified to do so by the officers of the City of Tulsa. (Ord. No. 55)

Section 354. TRASH

It shall be unlawful for any person to deposit, throw, place, or scatter or cause to be placed on any street, alley, sidewalk, gutter, or other public place within the City of Tulsa any filth, refuse, garbage, ashes, rubbish, grass, weeds, paper, or any animal or vegetable matter. (Ord. No. 499)

Section 356. OPEN GRATING

It shall be unlawful and an offense for any person to permit to be open or leave open any cellar door, manhole, or grating of any kind in or upon any street, sidewalk or alley of the City.

Section 357. DRAINAGE

No person shall permit any water, slops, or other liquids to drain into any street or alley or onto any sidewalk within the City. Provided, that the natural drainage of rainwater shall not be prohibited by the provisions of this section when the same is from natural elevations, in reasonable quantities as would naturally occur and which do not carry filth or other accumulations from off the private property into or onto said streets or alleys. (Ord. No. 499)

Title 40 - Waterworks and Sewage
Chapter 4. Spavinaw Water District
Section 62. HEALTH RULES

Whereas, the Commissioner of Health of the State of Oklahoma, has, for the preservation of the public health, promulgated, adopted, and put in force and effect in said Spavinaw Water District, the following Rules and Regulations, to-wit:

(e) Refuse Matters Not to be Discharged in Spavinaw Reservoir. No human excrement shall be deposited or discharged into the Spavinaw Reservoir or into any watercourse, as hereinbefore defined in paragraph (b); and no cesspool, privy, or other receptacle for the deposit of human excrement shall be located, constructed, or maintained within said Spavinaw Water District, unless such cesspool, privy or other receptacle be so constructed that no portion of its contents can escape or be washed into such waters, and shall not be located closer than 660 feet to water's edge.

(f) Same. No human excrement, or contents of any privy, cesspool, sewer, or other receptacle for the reception or storage of human excrement shall be deposited or discharged within said Spavinaw Water District or upon or into the ground at a place from which any such excrement, composit, or contents or particles thereof, may flow or be washed or carried into the Spavinaw Reservoir, or into any watercourse as hereinabove defined in paragraph (b).

(g) Same. No house slops, sink waste, water which has been used for washing or cooking, or other polluted water shall be discharged into the said Spavinaw Reservoir, or into any watercourse with said Spavinaw Water District; and no house slops, sink waste, water which has been used for washing or cooking, or other polluted water shall be discharged into or upon any ground in said Spavinaw Water District within 660 feet of the high water line of said Spavinaw Reservoir, or of any watercourse as hereinabove described in paragraph (b).

(h) Same. No garbage, manure, or putrescible matter whatsoever shall be put into the said Spavinaw Reservoir, or into any watercourse as hereinabove described in paragraph (b); and no garbage, manure, or putrescible matter whatsoever shall be put upon the ground in said Spavinaw Water District within 660 feet of the high water line of said Spavinaw Reservoir or of the high water line of any watercourse, as hereinabove defined in paragraph (b); or within any such greater distance as may from time to time be established either by the State Health Department or by the City of Tulsa.

(i) Same. No stable, pigsty, henhouse, barnyard, hog yard, hitching or standing place for horses, cattle, or other animals, or other place where animal manure is deposited or accumulated, shall be located, constructed, or maintained in said Spavinaw Water District, any part of which is within 660 feet of the high water line of any watercourse, as hereinabove defined in paragraph (b).

(j) Same. No refuse, industrial wastes, or other waste products or polluting liquids, or other substance of a nature poisonous or injurious, either to human beings or animals, or of such nature as would impart an objectionable taste or odor to any water into which it might be discharged, and no putrescible matter whatsoever shall be discharged directly into or at any place from which it may flow or be washed or carried into said Spavinaw Reservoir or into any watercourse, as hereinabove defined in paragraph (b).

(k) Approval State Department of Health; When. No system of sewers or other works for the collection, conveyance, disposal or purification of domestic or manufacturing sewage, wastes, or drainage, or any other putrescible matters whatsoever shall, except in accordance with plans first approved in writing by the State Department of Health, be constructed or maintained at any place within the Spavinaw Water District so called. No private or separate sewer shall be constructed or maintained in said Spavinaw Water District having an outlet upon or in the ground within 660 feet of the high water line of said Spavinaw Reservoir or of the high water line of any watercourse, as hereinabove defined in paragraph (b).

Title 40 - Waterwork and Sewage
Chapter 5. Requirements for Use of Sanitary Sewage System
Section 104. PROHIBITED CONNECTIONS

No roof, foundation drain, or surface water drainage pipe shall be connected so as to discharge water into a public sewer or house sewer. No structure shall be constructed and no condition created which will cause or permit the discharge of surface drainage of any type into any house or public sewer line. No septic tank shall be connected with the sanitary sewer system. No dam or obstruction shall be placed in any sanitary sewer except with the permission of the Superintendent.

Section 105. SWIMMING POOLS - PONDS

It shall be unlawful for any person to connect any swimming pool, wading pool, fish pond, or similar reservoir to the sewer system unless first granted permission by the Superintendent. Any person desiring to make such a connection shall make a written application to the Superintendent and if such application is approved, shall, before being issued said permit, execute a written agreement to the City stipulating that, (1) the reservoir shall not be drained except during the hours designated by the Superintendent; (2) the outlet orifice shall be a restricted diameter of a size to be designated by the Superintendent; (3) the owner shall hold the City harmless from liability for any damage resulting from such a connection; (4) and that the permit so issued is of a temporary nature and may be discontinued at any time the Superintendent deems it advisable for the safety and health of other users of said sanitary sewer line that the connection shall be discontinued.

Section 106. SEPARATE SANITARY SEWERS - EACH PREMISE

Each premise shall have a separate sanitary sewer connection, provided that where, after the public sewer has been constructed, the adjacent property has been platted, replatted, or the several buildings thereto relocated in such a manner that one or more are separated from the public sewer, then the Superintendent may require an extension of the main or lateral of the public sanitary sewer system so that the said public sewer could serve directly any building that has been separated from the existing public sewer; provided further such other requirements are met as to size of pipe, construction, and use as the Superintendent may deem necessary and that easements be granted to the public covering the location of the extended public sewers across intervening lots or tracts of ground.

Section 107. UNLAWFUL DISCHARGE

It shall be unlawful for any person to discharge, place, throw, or deposit or so place as to be carried in any public sewer or house sewer or works of the City of Tulsa, or into any sewer connected therewith, any of the following substances:

(a) General Restrictions: Grease, unground garbage, hair, feathers, hide, blood, paunch, dead animals, sand, cinders, ashes, stone dust, lime sludge, plastics, wood, mud, or any other solids likely to cause obstruction of flow in any such sewers or works; gas, tar, residues from petroleum storage, refining or process fuel, or lubricating oil, gasoline, naptha, or explosives or inflammable liquids or substances; cyanides, or cyanogen compounds, capable of liberating hydrocyanic gas on acidification; mineral acids, waste acid pickling or plating liquids, from pickling or plating of iron, steel, brass, copper, chromium, nickel, zinc, lead, or any other dissolved or solid substance which will endanger health or safety, interfere with the flow of sewers, attach or corrode sewers or sewage treatment structures or otherwise interfere with the operation of the sewers or works of the City of Tulsa.

(b) Specific Restrictions:

(1) Acidity or alkalinity must be neutralized so that the average daily pH will be in the range of pH 6.0 to pH 8.0, with a maximum temporary variation of pH 6 to pH 10.

(2) Must not contain more than ten parts per million of the following gases: hydrogen sulfide, sulphur dioxide, nitrous oxide, or any of the halogens.

(3) Must not contain any explosive substance.

(4) Must not contain any inflammable substance with a flash point lower than 187° F.

(5) Must not contain grease or oil or other substances that will solidify or become viscous at temperatures between 32° to 150° F.

(6) Must have a temperature with the range of 32° to 150° F.

(7) Must not contain soluble substances or concentrations that would increase the viscosity to greater than 1.1 specific viscosity.

Title 51 - Building Code
Chapter 12. Safeguards During Construction
Section 1213. STORAGE OF MATERIAL

1213.1 Within Building

Materials or equipment needed in a building operation, if stored within the building, shall be so placed that they will not load any part of the construction in excess of the design load, nor interfere with the safe prosecution of the work.

1213.2 Outside Building

(a) Materials and equipment shall not be stored in a street, alley, sidewalk, or any other public space except by special permission of the municipality.

(b) In whatever manner building material may be stored or equipment set up in a street, a safe walkway not less than 4 feet wide, unobstructed for its full length and adequately lighted at all times shall be maintained for use of the public.

1213.3 Covering Material

Materials stored within the building or within 10 feet of the building which require covering shall be protected by noncombustible material.

Section 1214. DISPOSAL OF WASTE

Waste material and rubbish shall not be stored nor allowed to accumulate within the building or in the immediate vicinity, but shall be removed from the premises as rapidly as practicable. No material shall be disposed of by burning on the premises or in the immediate vicinity without permission from the municipality. Dry material or rubbish shall be wetted down, if necessary, to lay dust or prevent being blown about.

Chapter 18. Use of Streets and Alleys During Construction
Section 1808. MORTAR, CEMENT - PREPARING

Lime, cement, or other mortar and concrete may be prepared upon any street within the space designated in this code, to be used or occupied for building purposes. If such mortar or concrete is prepared or deposited upon the roadway, sidewalk, or parkage, it shall be upon a light bed of tongued and grooved boards, placed upon two-inch bearers or sleepers, leaving an air space below, and shall be properly protected so as to prevent any splashing or dripping on the parkage, roadway, or sidewalk. It shall be unlawful for any person to prepare or deposit concrete or mortar of any description, or any similar mixture upon the unprotected surface of any pavement, parkage, or sidewalk.

Section 1809. EMERGENCY PRECAUTIONS

The Building Inspector shall be empowered hereby to use his discretion in enforcing additional measures not specifically required by this code, to safeguard the public and all property interests against injury, loss, or damage as the occasion may arise when streets, sidewalks, or alleys are used for the storage and handling of materials or any other purpose connected with any building operation in the corporate limits of the City of Tulsa. (Ord. No. 5374)

Title 56. Plumbing Code
Chapter 12. Drainage System
Section 152. BUILDING SEWER

(d) Sanitary and Storm Sewers. Where separate systems of sanitary drainage and storm drainage are installed in the same property, the sanitary and storm building sewers or drains may be laid side by side in one trench.

Chapter 14. Storm Drains
Section 177. GENERAL

(a) Drainage Required. Roofs, paved areas, yards, swimming pools, courts and courtyards, the drainage of which discharge onto public property, shall be drained into a storm sewer system where such a system is available. Permit applicants must first check with the office of the City Engineer.

(b) Prohibited Drainage. Storm water shall not be drained into any sanitary sewer system.

Chapter 15. Septic Systems

Section 186. PERMIT REQUIRED

Before any person shall construct, repair, or install any septic tank system within the corporate limits of the City of Tulsa, within five miles of the City Corporate limits, or outside of the City of Tulsa wherever the plumbing system is connected directly or indirectly with the Water Works System of the City of Tulsa, he shall obtain a permit therefor from the Plumbing Inspector, and the refusal, failure, or neglect to obtain such a permit before commencing such construction or installation shall be unlawful, and each day thereafter in which such work shall be done, shall be unlawful and a separate offense.

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APPENDIX E

STATE OF OKLAHOMA INSTREAM WATER QUALITY CRITERIA FOR THE ARKANSAS AND VERDIGRIS RIVERS AND THEIR INTERSTATE TRIBUTARIES

All storm water runoff from Urban Tulsa flows either directly or indirectly into the Arkansas River or the Verdigris River. Therefore, it is important to include in this study the State of Oklahoma's water quality criteria for both major receiving streams. These criteria are essentially identical for the two rivers, with the exception that the Verdigris River and its interstate tributaries provide more favorable public and private water supplies, but are not designated for the production of hydroelectric power. The water quality standards for the Arkansas River and interstate tributaries are quoted below (11):

> The water quality criteria for the Arkansas River and interstate tributaries, are based on the present and potential uses, and on existing quality data. The proposed criteria shall serve as guidelines to control pollution and to maintain the best quality which will result in an equitable balance of social and economic benefits to the State. It is realized that the criteria cannot be considered as permanently fixed. Future changes in cultural activities, the development of additional quality data, enhancement of existing quality by further removals of dissolved solids, and improvements in waste treatment technology may necessitate revisions of the criteria. The proposed criteria are applicable at all times and at all flows, except as otherwise indicated.
>
> ## I. Arkansas River and Interstate Tributaries
>
> ### A. Water Uses
>
> The Arkansas River and Interstate Tributaries above the Kaw Reservoir Dam are used, or may be used for fish and wildlife propagation, agriculture, hydroelectric power, aesthetics, public water supplies, industrial supplies, and to receive treated wastes. Inflows from the Salt Fork Arkansas River and the Cimarron River result in a high degree of mineralization and a quality

less than desirable for public water supplies and similar uses requiring water of higher quality. However, due to the shortage of waters in the area of more suitable quality, it is expected that off-channel storage will be developed for diverting flows of suitable quality for domestic use. Less than desirable quality through the Tulsa area has discouraged general development for higher quality uses. The mineral quality improves below Keystone Dam to the Arkansas State Line. Further improvements in quality through flow regulation and control of natural and manmade pollutants should result in a quality suitable for a wider range of beneficial uses.

B. General Criteria

All tributary streams and all waste effluents shall be in such condition that when discharged to the Arkansas Rivers and Interstate Tributaries, they shall not create conditions which will adversely affect public health, or use of the water for beneficial purposes.

C. Specific Criteria

1. Mineral Quality-Historic data on stream flow and mineral quality has been published in reports entitled, "Chemical Character of Surface Water of Oklahoma," water years 1947 through 1964, and "Water Quality Records in Oklahoma," for the 1964 water year. Statistical summaries of these records... will serve as interim guidelines for control of water quality.

   It is recognized that the present water quality of the Arkansas River and Interstate Tributaries, particularly the Salt Fork Arkansas and Cimarron Rivers, is less than desirable with significant contributions of minerals from natural as well as manmade sources. These criteria have the objective of enhancement of water quality by preventing further degradation at this time with the intent of improving the quality as the plans for removing the major natural salt sources are implemented and manmade pollution is further controlled. Quality management objectives, insofar as is practical, will be directed toward securing a water of higher quality.

2. Bacteria

In evaluating biological quality of waters and the use and value of such waters for beneficial purposes, consideration will be given by the appropriate regulatory authority to the results of a sanitary survey covering the drainage areas and stream reaches that may effect such biological quality. Waste discharges into waters used or capable of being used for domestic water supplies or body contact aquatic sports including skiing and swimming, shall receive disinfection or equivalent treatment as necessary for compliance with the following requirements.[4]

a. At the point of intake for treatment of waters used as public water supplies, bacteria of the coliform group shall not exceed 5,000/100 ml as monthly average[5] value (either MPN or MF count); nor exceed this number in more than 20% of the samples examined during any month; nor exceed 20,000/100 ml in more than 5% of such samples.

b. In all areas designed as recreational areas for body contact aquatic sports, including swimming and skiing, bacteria of the coliform group shall not exceed 1,000/100 ml as a monthly average[5] value (either MPN or MF count) during the recreational season; nor exceed this number in more than 20% of samples examined during any one month; nor exceed 2,400/100 ml (MPN or MF count) on any day except during periods of storm water runoff. Provided, however, that the fecal coliform shall not exceed a geometirc mean of 200/100 ml, nor shall more than 10% of total samples during any 30-day period exceed 400/100 ml.

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[4] Bacteriological criteria is tentative pending release of recommendations by the National Technical Task Committee on bacterial parameters for public water supply, recreation and irrigation and subsequent approval by appropriate state and federal water pollution control agencies.

[5] Logarithmic average based on a minimum of five samples per 30 days.

c. Bacterial concentrations of other than natural origin will be maintained below levels detrimental to beneficial uses.

3. Oil and Grease - Essentially free of floating or emulsified oil or grease.

4. Solids - Free of floating debris, bottom deposits, scum, foam, and other materials of a persistent nature from other than natural sources.

5. Turbidity - Turbidity of other than natural origin shall not cause a substantial visible contrast with the natural appearance of the water or be detrimental to beneficial uses.

6. Color - Color producing substances of a persistent nature from other than natural sources shall be limited to concentrations which will not be detrimental to beneficial uses.

7. Temperature - Differential changes in temperature from other than natural sources shall be limited to a maximum of 5° F provided the maximum temperature due to manmade causes shall not exceed 70° F in trout streams, 75° F in small-mouth bass streams, or 93° F in warm water streams.

8. Taste and Odor Producing Substances - Taste and odor producing substances shall be limited to concentrations that will not interfere with the production of potable water by modern treatment methods or impart off color or unpalatable flavor to the flesh of fish, or result in offensive odors in the vicinity of the water, or otherwise interfere with beneficial uses.

9. Dissolved Oxygen - The dissolved oxygen concentration shall not be less than 4 mg/l, except that this limitation of 4 mg/l will not be applicable in the

immediate vicinity of the point of waste discharge when the stream flow is less than 200% of the waste flow. In addition, the relationship of dissolved oxygen, biochemical oxygen demand and chemical oxygen demand of waste releases, and the flow characteristics of the stream shall not create conditions down-stream that are detrimental to beneficial uses.

10. Toxic Substances - Toxic Substances shall not be present in such quantities as to cause the waters to be toxic to human, animal, plant, or aquatic life. For aquatic life, using bioassey techniques, the toxic limit shall not exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the regulatory authority.

11. Radioactivity - The average concentration of the radionuclide (or radionuclides) in water at points of release from the control of the user shall not exceed the limits prescribed for such releases in the applicable portion of the current set of Radiation Protection Regulations, as promulgated by the Oklahoma State Board of Health or subsequent revisions thereof. A reasonable effort shall be made to identify each radionuclide, and to determine its concentrations, which is present in the effluent.[6]

12. pH - The pH shall be between 6.5 and 8.5. pH values below 6.5 and above 8.5 must not be due to waste discharge.

13. Other Substances - The control of other substances not heretofore mentioned will be guided by the U. S. Public Health Service Drinking Water Standards of

---

[6] Wherever reference is made to a current standard and to a "subsequent revision thereof," it is implied that such revisions will be officially approved by appropriate state and federal agencies prior to becoming official state or federal criteria respectively.

1962, or latest revision thereof, and accumulated scientific data on limits above which injury to use occurs. Pollutional substances will be maintained below maximum permissible concentrations for public water supplies, recreation requirements, agricultural needs, and other beneficial uses.

II. Tributaries to the Arkansas River

The quality of tributary streams shall be controlled so that the quality of the Arkansas River and Interstate Tributaries will not be lowered beyond the criteria set forth above. In addition, adequate control shall be maintained to prohibit the development of public health hazards or nuisance conditions in such tributaries and maintain the highest current beneficial use of the waters pending a determination of best usage and the establishment of specific criteria.

APPENDIX F.

CITY OF TULSA STORM DRAIN SYSTEM INCLUDING TEST AREA BOUNDARIES

The following plates were made by overlaying the City of Tulsa's Storm Drain System on TMAPC's 1:600 Land Use Maps. The Storm Drain System overlays were drawn to this scale utilizing the City of Tulsa's Official 1:200 Storm Drain Atlas and maps. The purpose of this task was twofold. First, the project's test area boundaries had to be defined to better understand the drainage patterns and to outline the drainage area for a land use retrieval within the test areas. Second, the maps will provide TMAPC with working maps to define subdrainage storm water runoff sheds for planning and management purposes.

LEGEND FOR FIGURES F-1 THROUGH F-15

Symbol	Item
—	Natural drainage boundaries
▮▮▮▮▮▮▮▮	Boundaries used in data retrieval for the test areas
≈≈≈	Open drainage
24"	Covered drainage conduit
▲(2)	Sampling site location
⬢	Rain gage location

FIGURE F-1
TEST AREA NO. 1

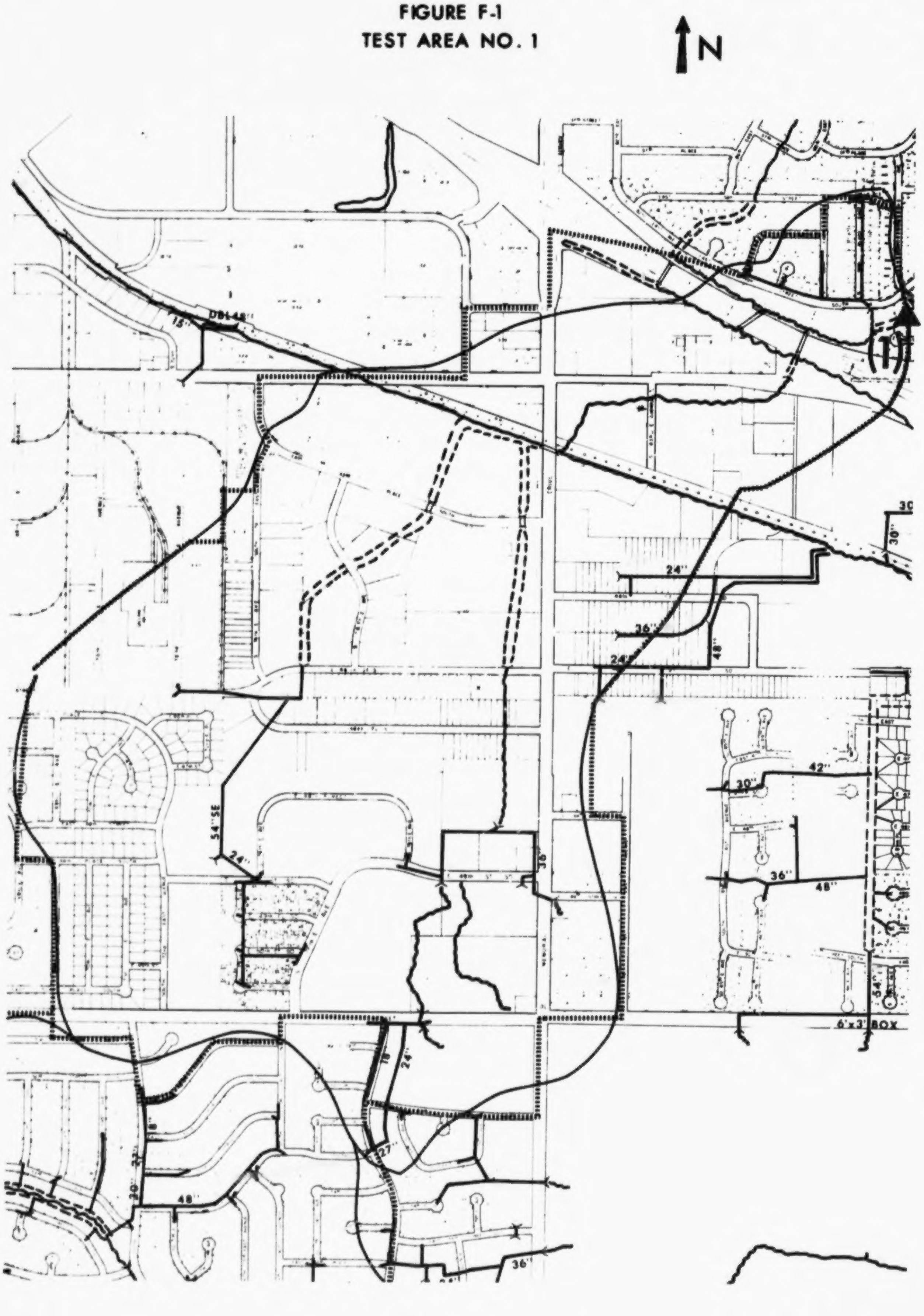

N
15"
DBL48"
30"
24"
36"
48"
24"
42"
30"
36"
48"
54"
6'x3' BOX
54" SE
24"
30
18"
24"
27"
18"
30"
48"
36"
24"
1

FIGURE F-2
TEST AREA NO. 2

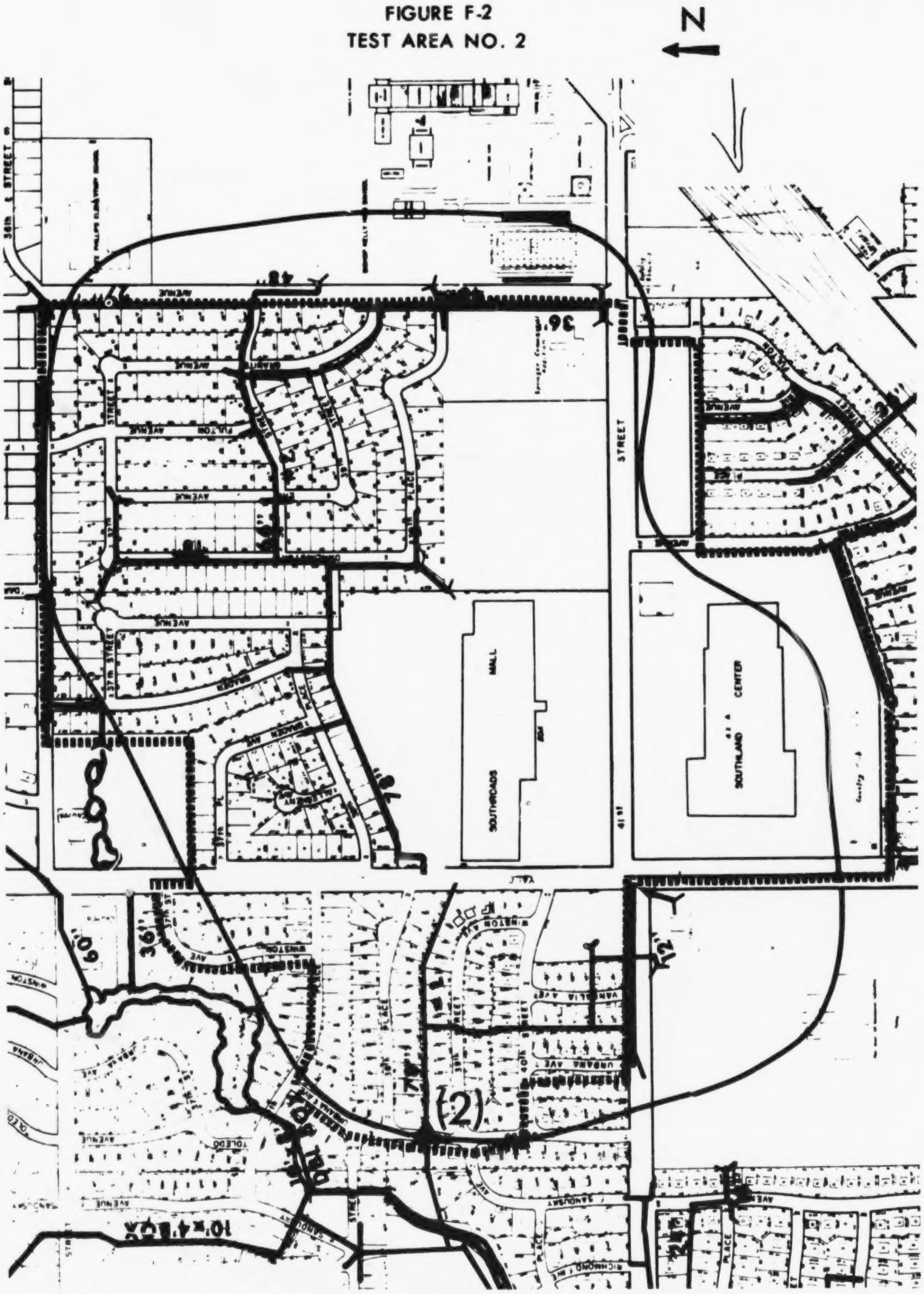

N
48"
36"
36"
60"
12"
10'x4' BOX
(2)
SOUTHROADS MALL
SOUTHLAND CENTER
41st STREET
36th STREET
37th STREET
AVENUE
WINSTON
TOLEDO
SANDUSKY
URBANA AVE
VANDALIA AVE
RICHMOND
PLACE

FIGURE F-3
TEST AREA NO. 3

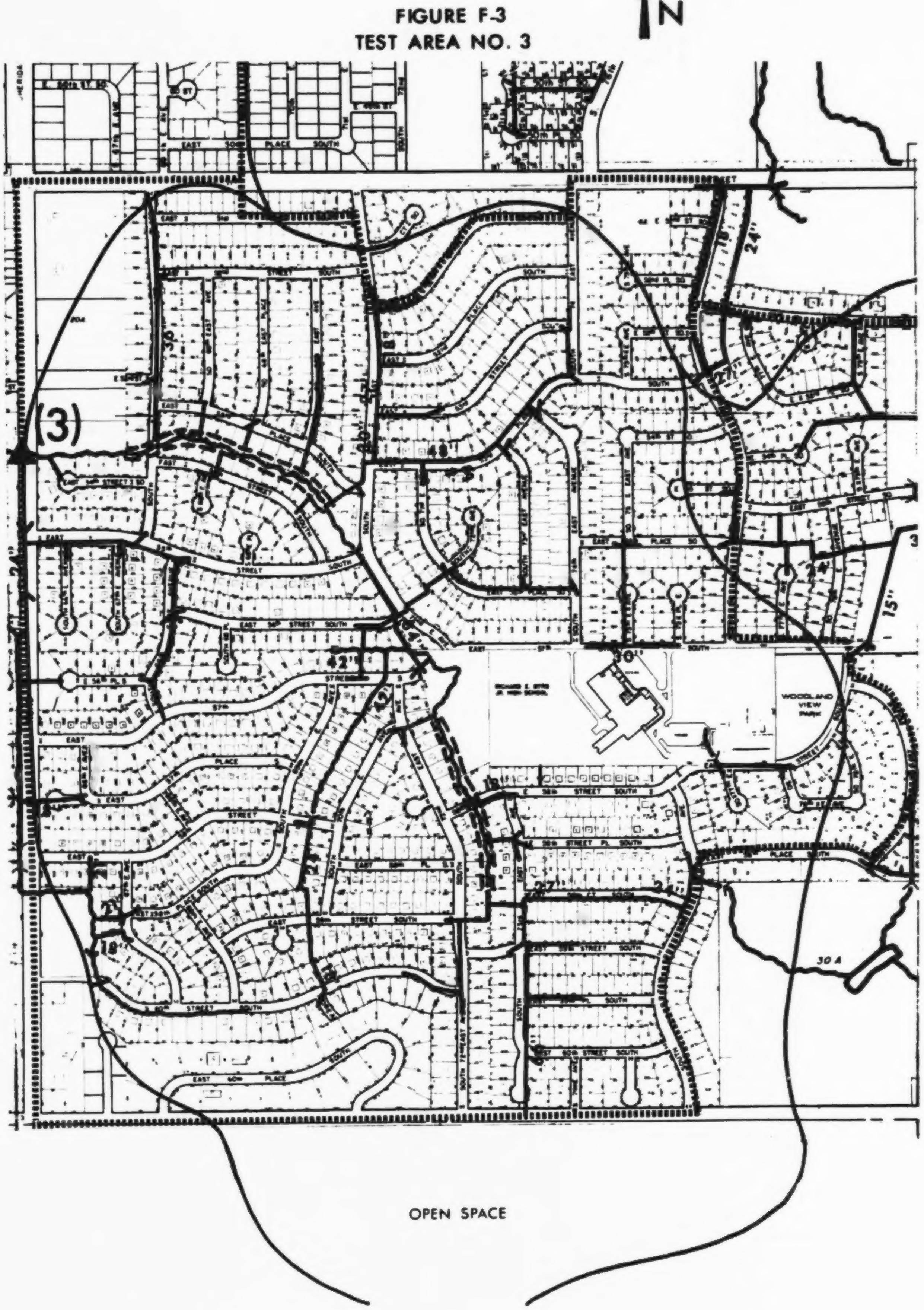
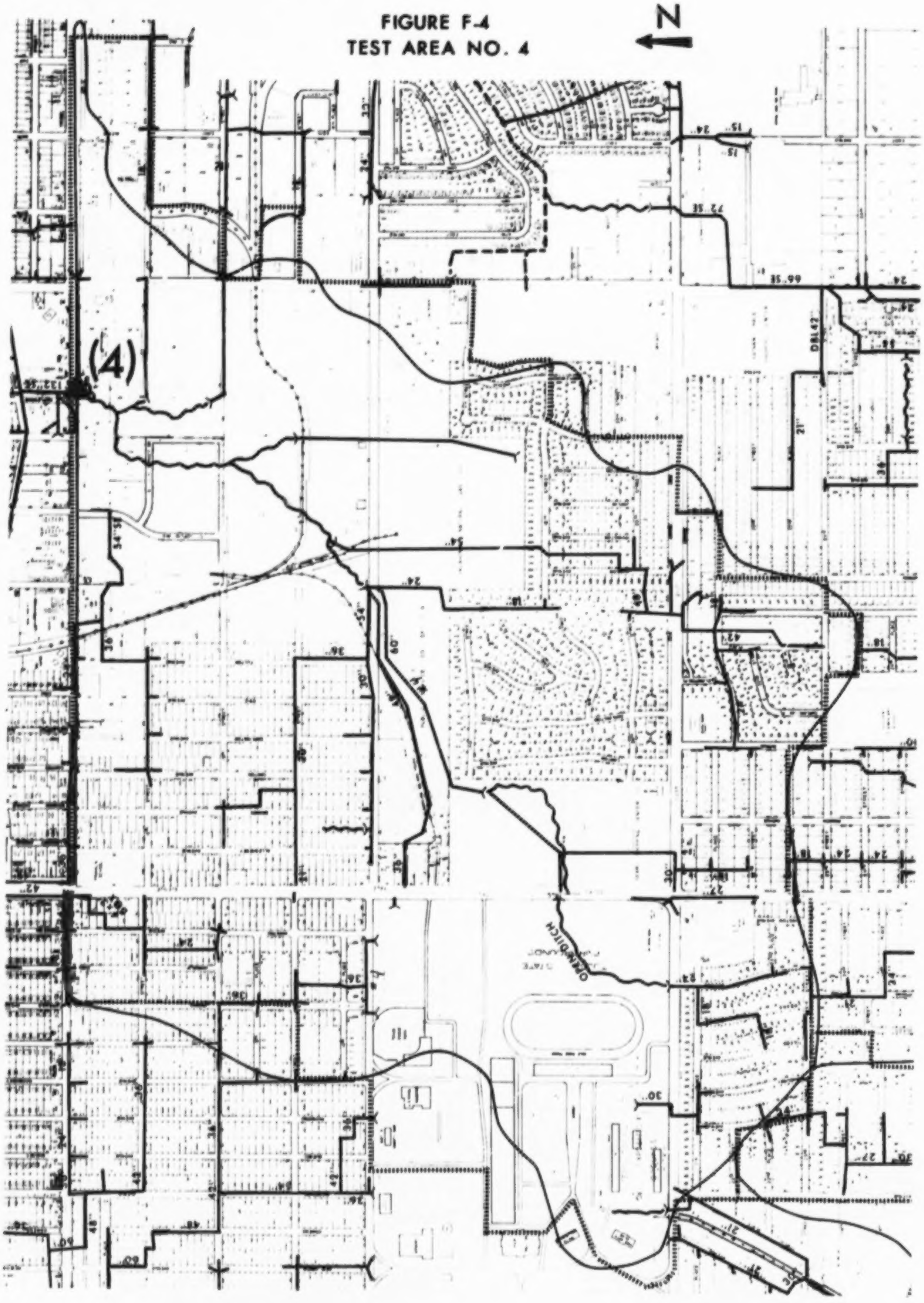

N
(3)
24"
36"
48"
42"
30"
15"
18"
24"
30 A
WOODLAND VIEW PARK
OPEN SPACE

FIGURE F-4
TEST AREA NO. 4



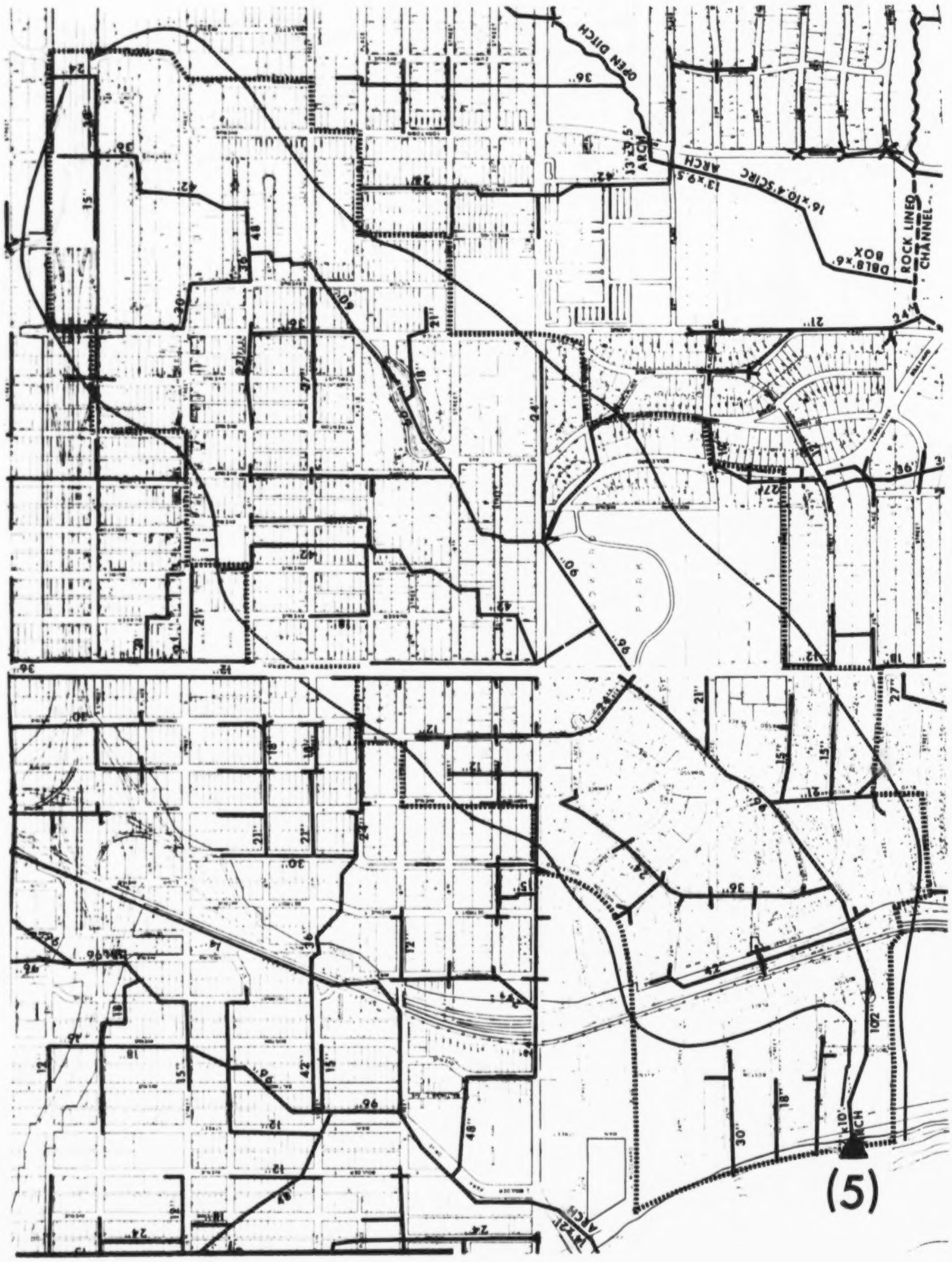


FIGURE F-5
TEST AREA NO. 5

N

OPEN DITCH
13'×9.5' ARCH
16'×10.4'SCIRC ARCH
13'×9.5'
DBL 8'×6' BOX
ROCK LINED CHANNEL
(5)
ARCH

FIGURE F-6
TEST AREA NO. 6

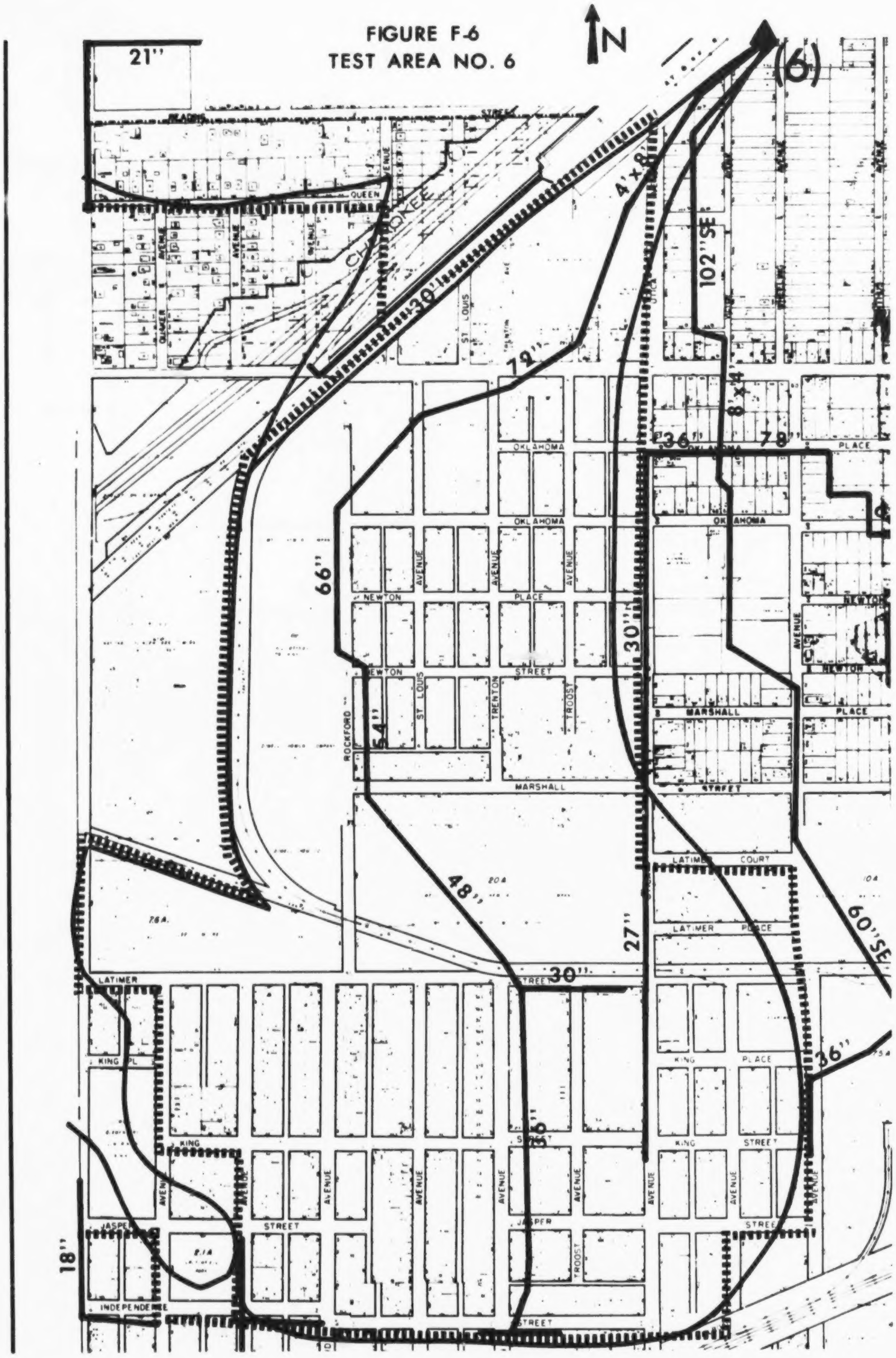

N
(6)
21"
READING
STREET
QUEEN
QUINCY
CHEROKEE
30"
4'x8'
102"SE
ST LOUIS
TRENTON
72"
8'x4'
36"
78"
OKLAHOMA
PLACE
OKLAHOMA
NEWTON
PLACE
66"
30"
AVENUE
NEWTON
STREET
ROCKFORD
ST LOUIS
TRENTON
TROOST
54"
MARSHALL
PLACE
MARSHALL
STREET
LATIMER
COURT
LATIMER
PLACE
48"
27"
60"SE
30"
STREET
LATIMER
KING PL
KING
PLACE
KING
STREET
36"
JASPER
STREET
TROOST
INDEPENDENCE
STREET
18"

FIGURE F-7
TEST AREA NO. 7

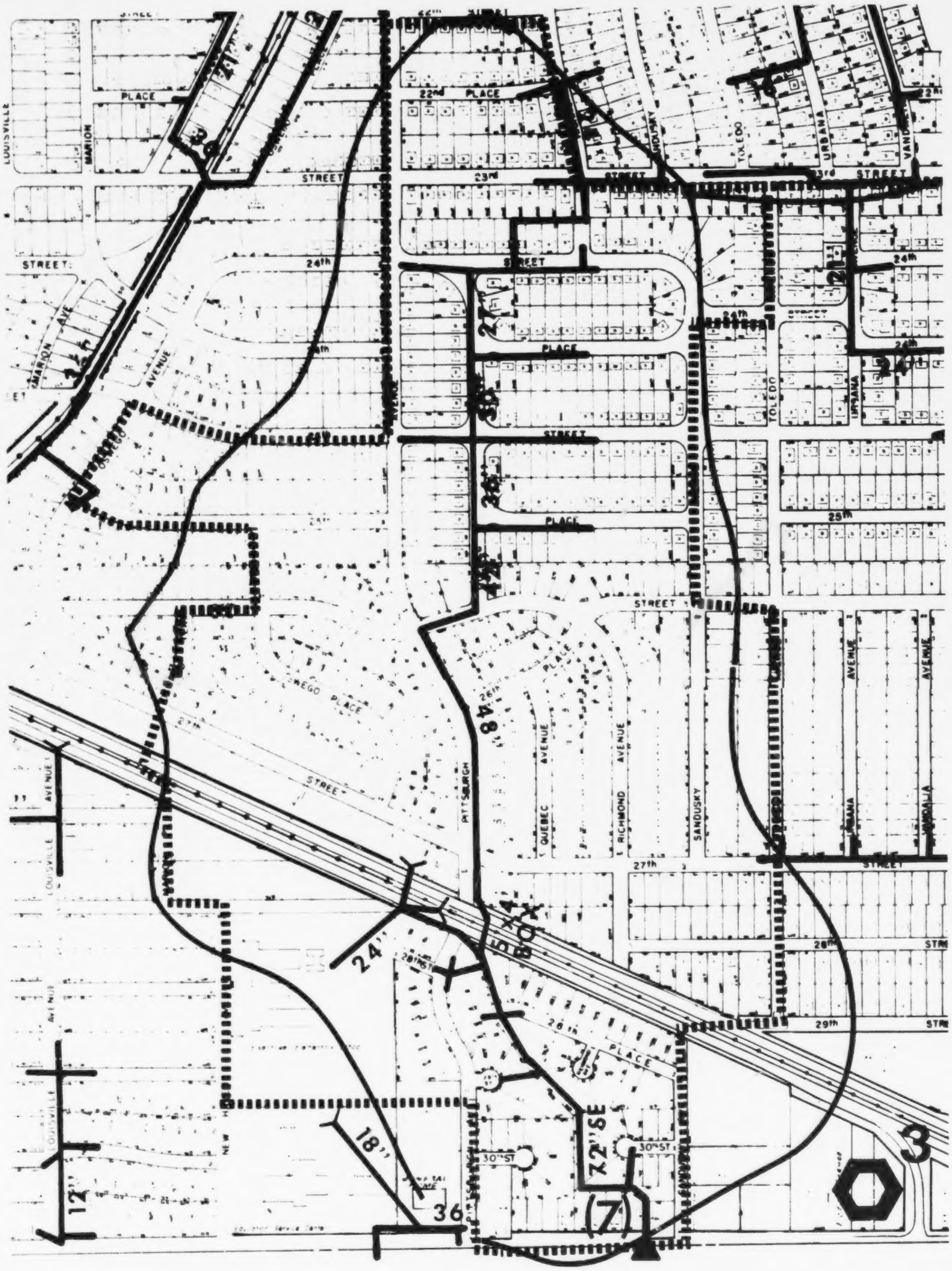

N
22nd PLACE
23rd STREET
24th STREET
24th PLACE
25th
26th PLACE
27th STREET
28th PLACE
28th ST
29th
30th ST
LOUISVILLE
MARION
MARION AVE
TOLEDO
URBANA
VANDALIA
PITTSBURGH
QUEBEC AVENUE
RICHMOND AVENUE
SANDUSKY
OSWEGO PLACE
48"
24"
18"
12"
36
72" SE
(7)
3

FIGURE F-8
TEST AREA NO. 8

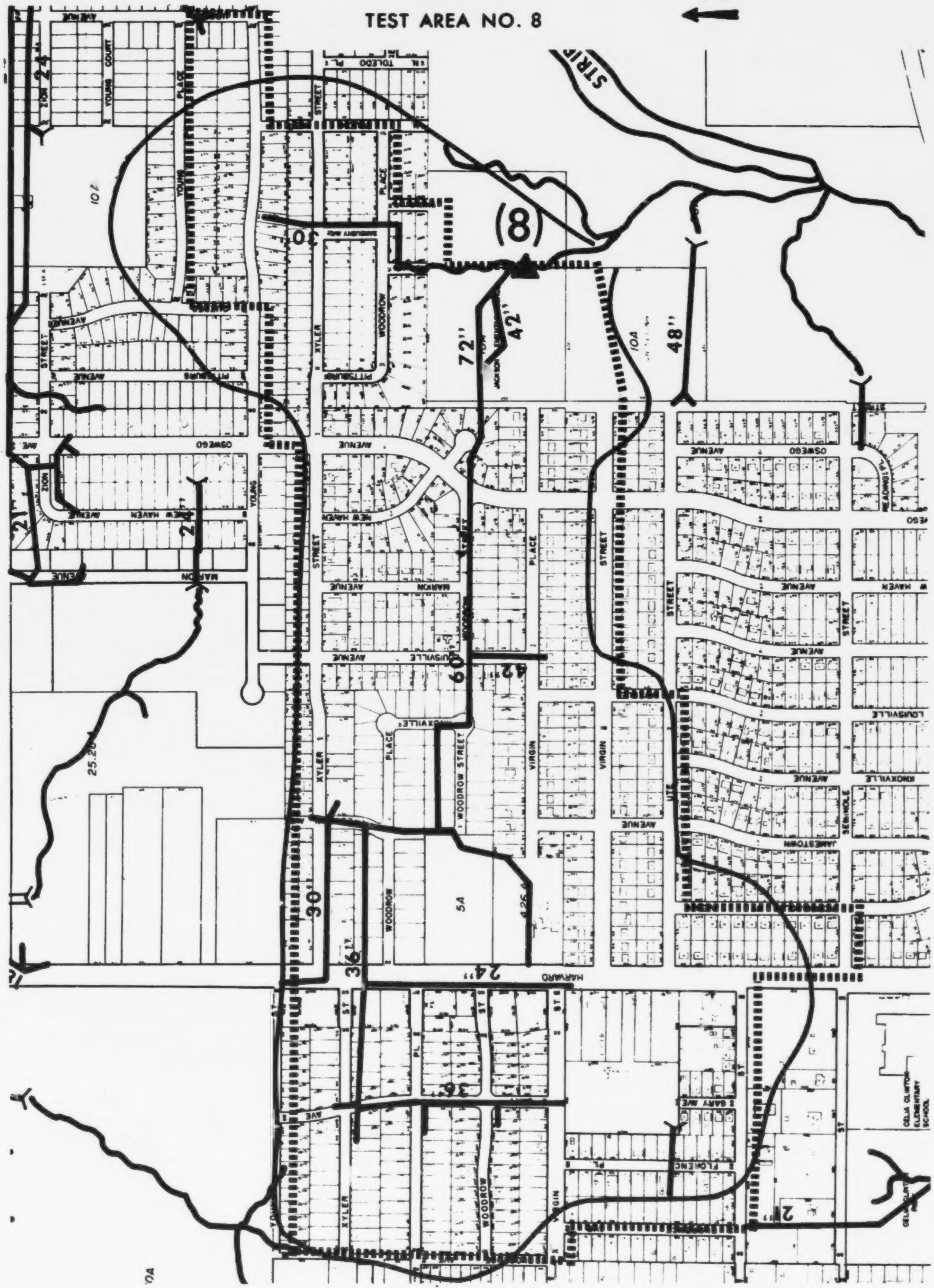

N
(8)
72''
42''
48''
30''
60''
36''
24''
30
24
42
36
5A
10A
XYLER STREET
WOODROW STREET
VIRGIN PLACE
VIRGIN STREET
UTZ STREET
YOUNG STREET
HARVARD
OSWEGO AVENUE
NEW HAVEN AVENUE
MARION AVENUE
LOUISVILLE AVENUE
KNOXVILLE
JAMESTOWN
SEMINOLE
PITTSBURG AVENUE
TOLEDO PL.
CELIA CLINTON ELEMENTARY SCHOOL

FIGURE F-9
TEST AREA NO. 9

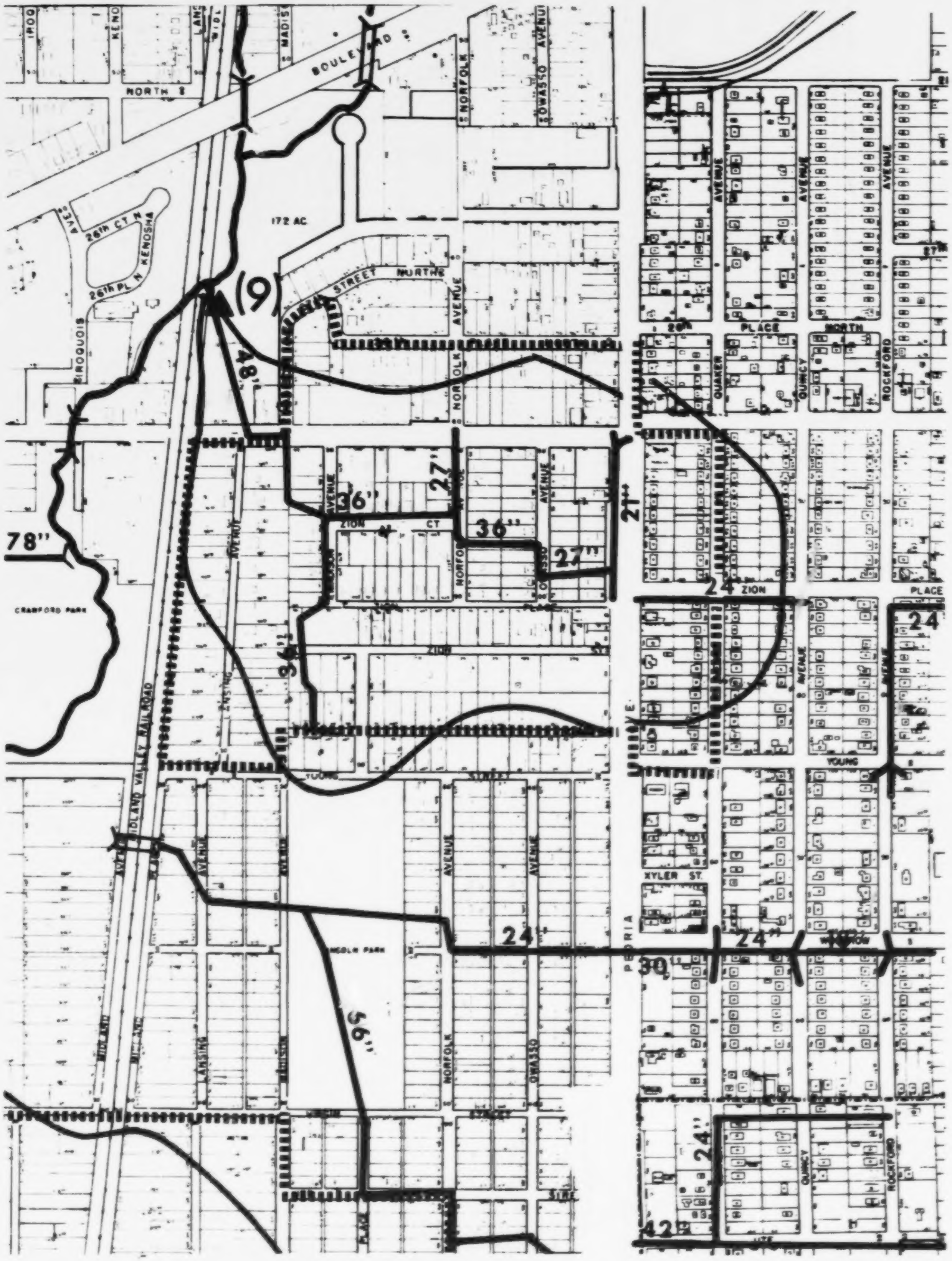

N
(9)
78"
48"
36"
27"
36"
36"
27"
21"
24"
24
24"
24"
30
56"
24"
42
BOULEVARD
NORTH
26th CT N
26th PL N KENOSHA
IROQUOIS
172 AC.
STREET NORTH
NORFOLK
OWASSO AVENUE
AVENUE
ZION CT
ZION
ZION
PLACE
QUAKER
QUINCY
ROCKFORD
28th PLACE NORTH
YOUNG
YOUNG STREET
XYLER ST.
PEORIA
MIDLAND VALLEY RAILROAD
LANSING
MADISON
CRAWFORD PARK
LINCOLN PARK

FIGURE F-10
TEST AREA NO. 10

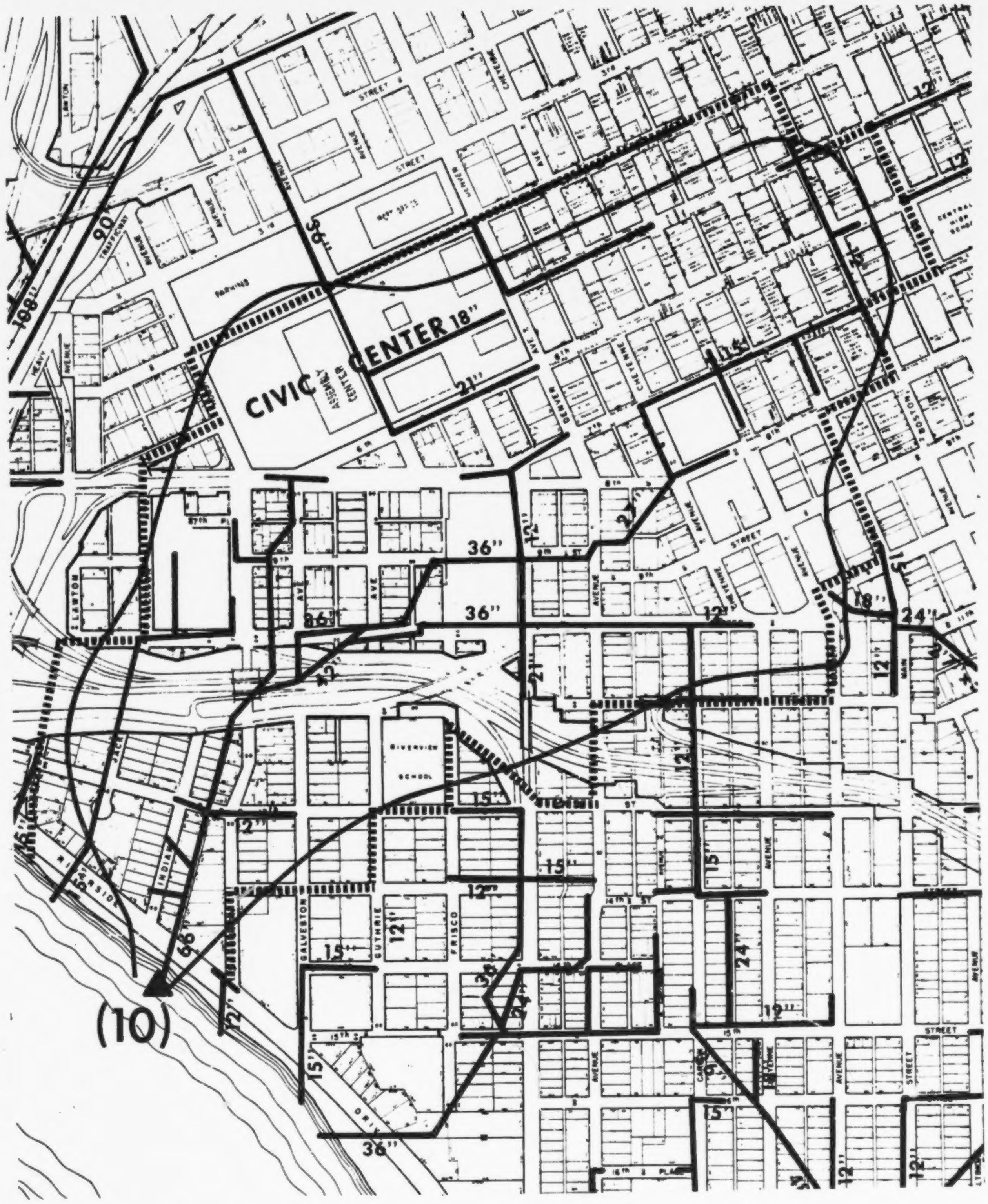

N
CIVIC CENTER
ASSEMBLY CENTER
PARKING
RIVERVIEW SCHOOL
CENTRAL HIGH SCHOOL
(10)
108"
90"
96"
18"
21"
24"
36"
36"
36"
66"
42"
21"
12"
15"
15"
12"
15"
12"
15"
12"
24"
18"
24"
12"
15"
12"
24"
36"
12"
12"
15"
12"
12"
36"
STREET
AVENUE
DENVER
CHEYENNE
BOSTON
MAIN
GALVESTON
GUTHRIE
FRISCO
LAWTON
RIVERSIDE
DRIVE

FIGURE F-11
TEST AREA NO. 11

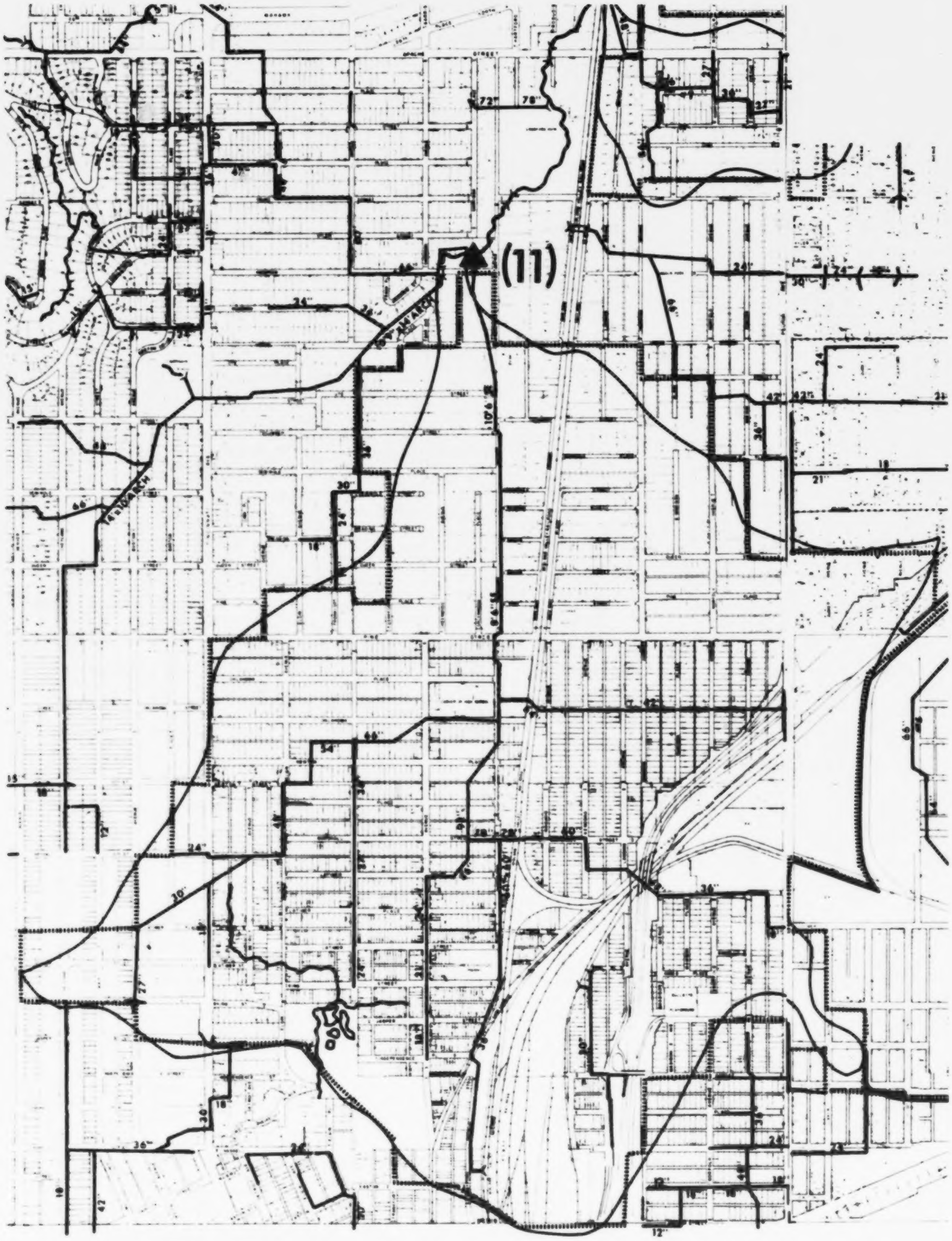
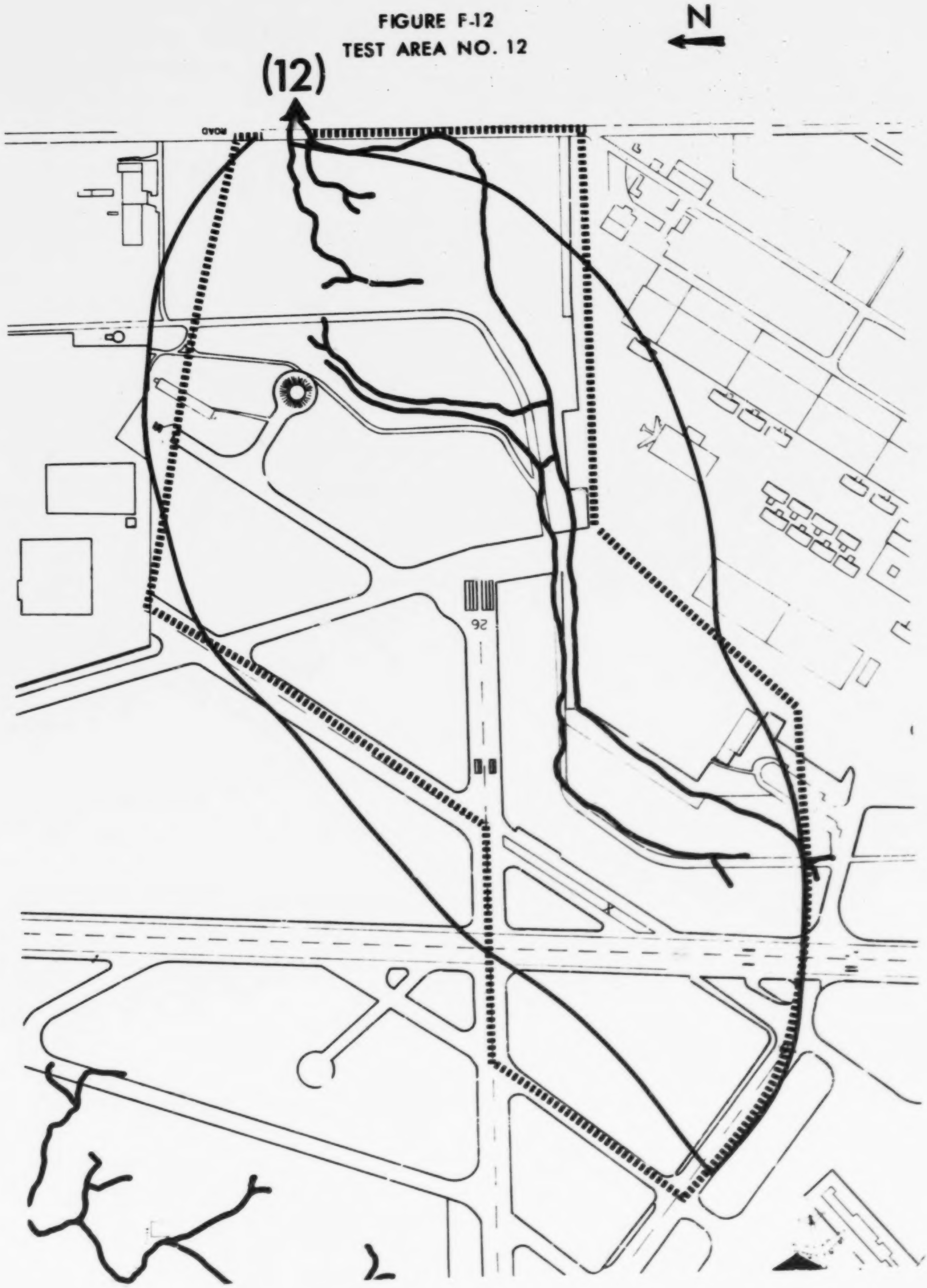


FIGURE F-12
TEST AREA NO. 12



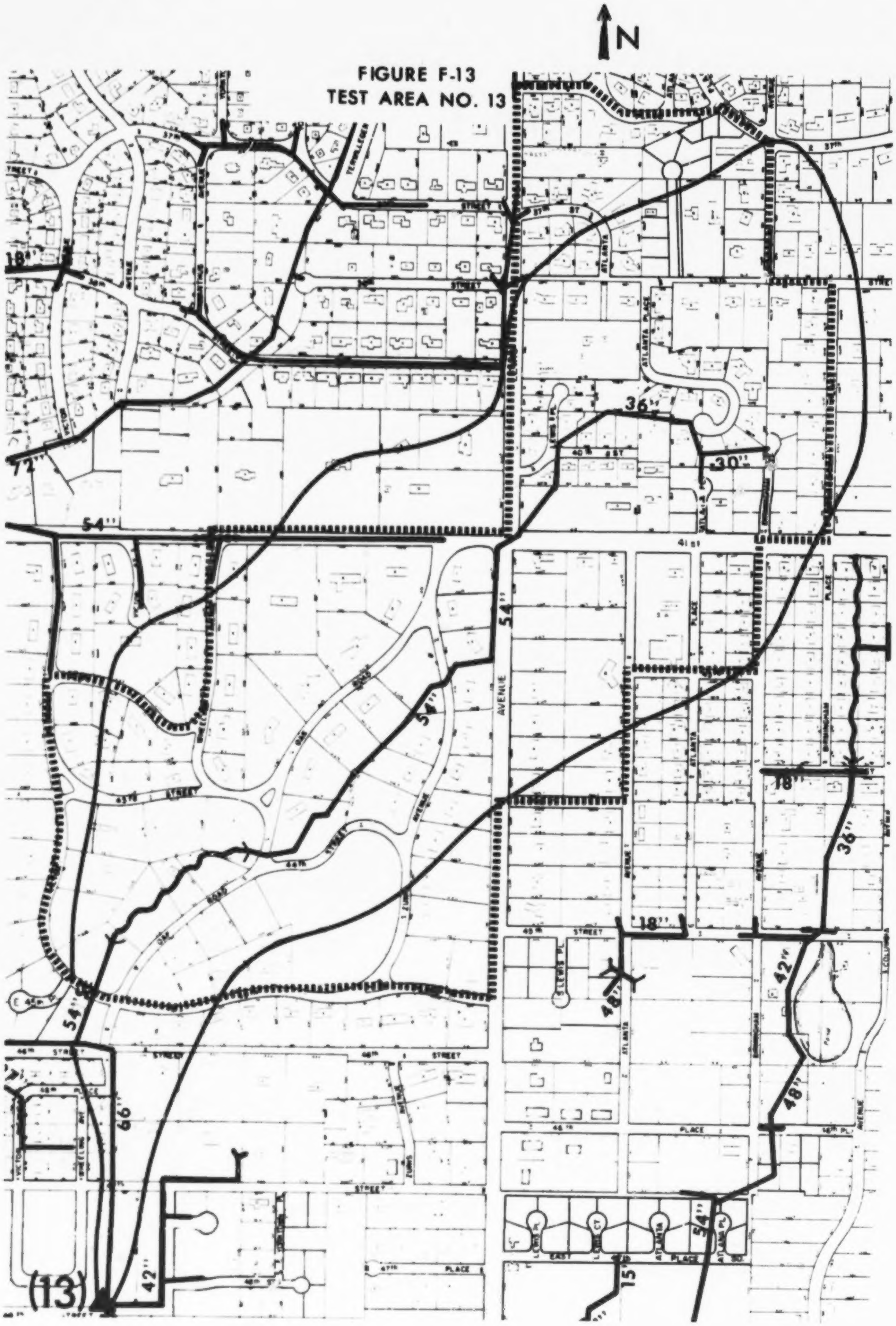


FIGURE F-13
TEST AREA NO. 13

N
18"
72"
54"
36"
30"
54"
54"
54"
18"
36"
18"
42"
48"
48"
54"
66"
42"
15"
(13)
AVENUE
41 st
40th ST
37th
36th
STREET
46th
STREET
46th PLACE
PLACE
47th PLACE
ATLANTA
ATLANTA PLACE
LEWIS PL.
BIRMINGHAM
VICTOR
WHEELING AVE

FIGURE F-14
TEST AREA NO. 14

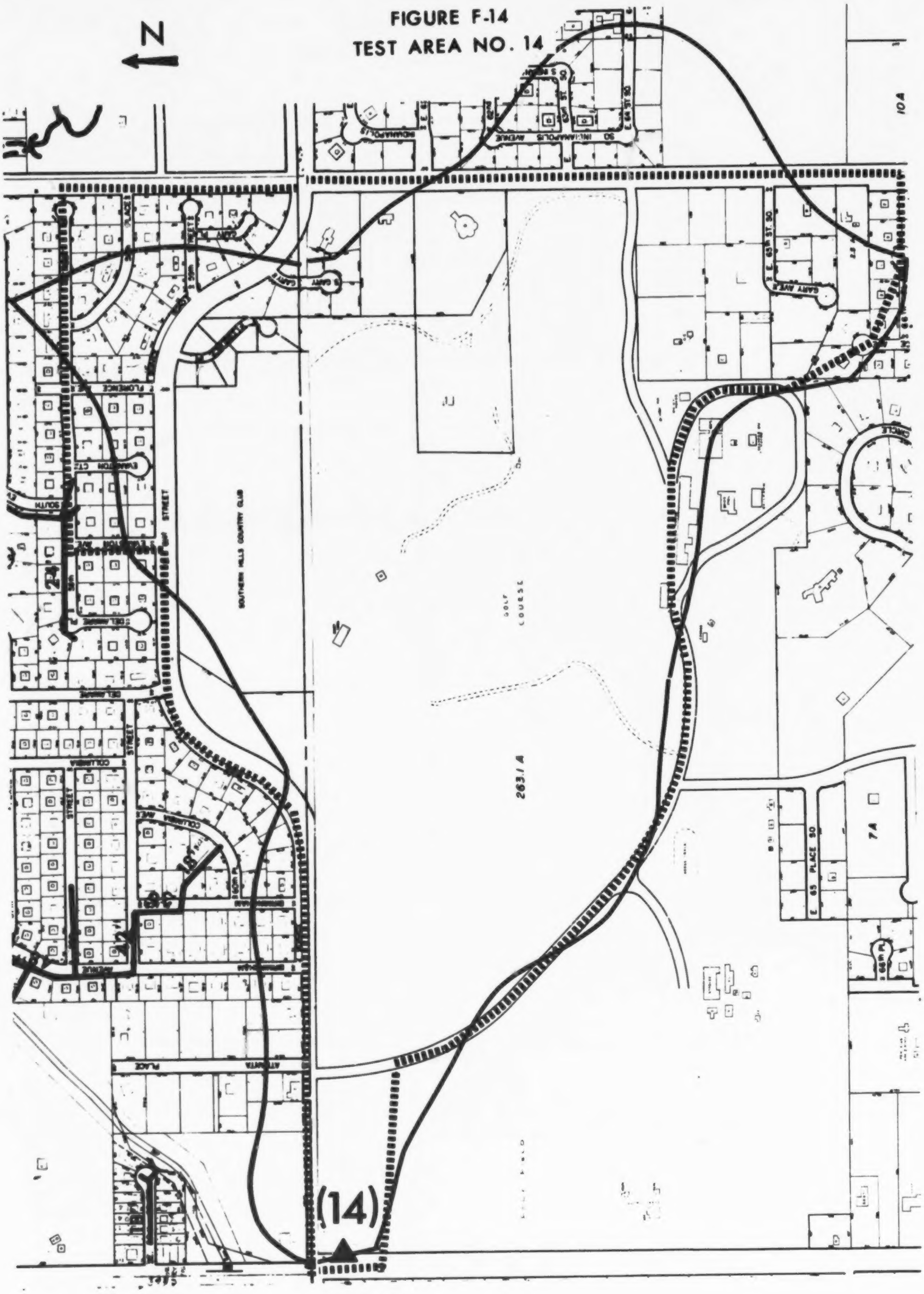
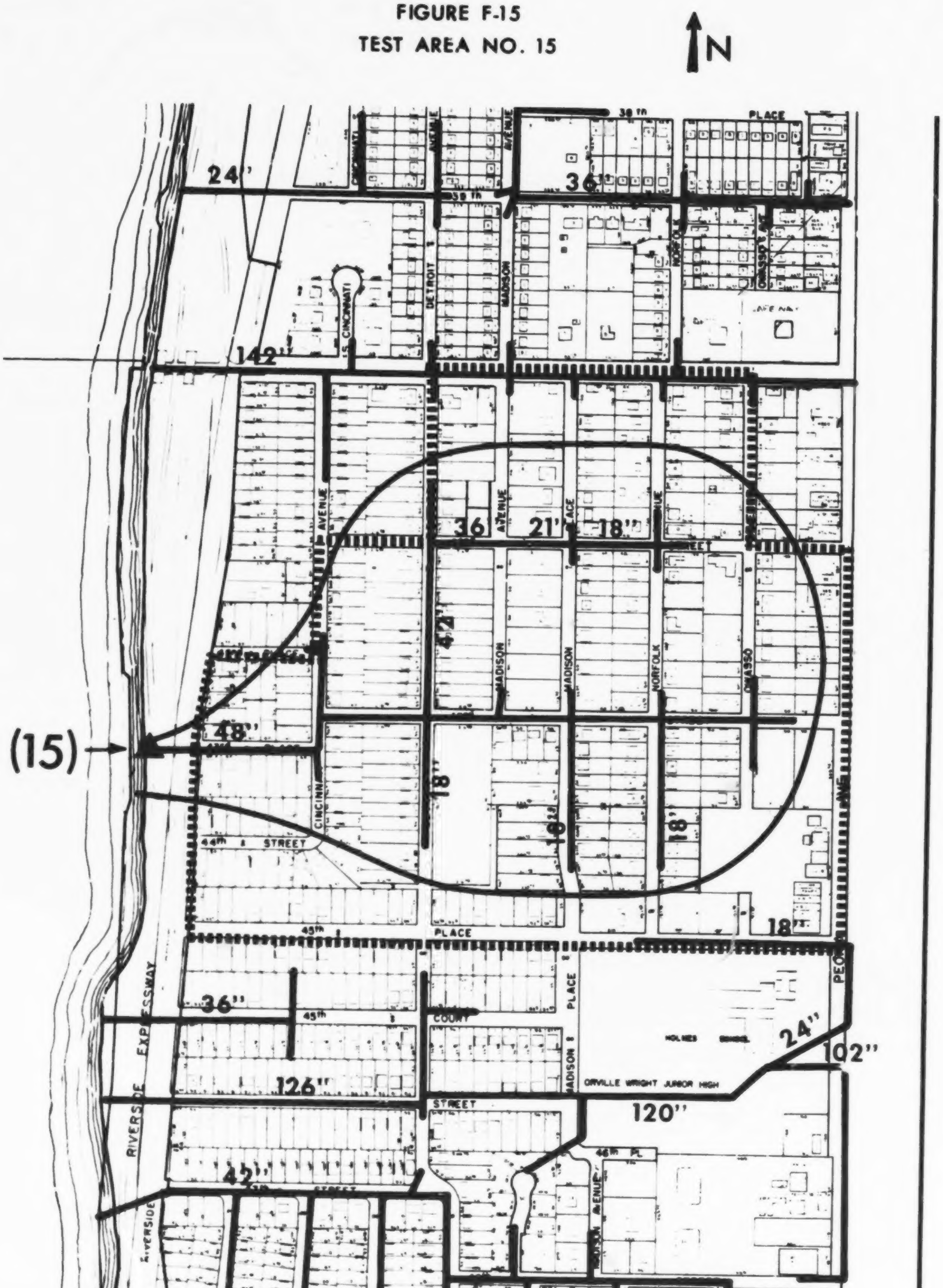

N
SO. INDIANAPOLIS AVENUE
SOUTHERN HILLS COUNTRY CLUB
GOLF COURSE
263.1 A
10 A
7 A
STREET
(14)

FIGURE F-15
TEST AREA NO. 15


N
(15)
24"
36"
142"
36
21"
18"
42"
48"
18"
18"
18"
18"
36"
126"
42"
24"
102"
120"
RIVERSIDE EXPRESSWAY
RIVERSIDE
CINCINNATI
DETROIT
MADISON
NORFOLK
OWASSO
AVENUE
PLACE
STREET
44th STREET
45th PLACE
45th COURT
46th PL.
PEORIA
HOLMES SCHOOL
ORVILLE WRIGHT JUNIOR HIGH
39th PLACE

APPENDIX G

FEDERAL WATER QUALITY ADMINISTRATION STORET II SAMPLING STATION CODE NUMBERS

All storm water quality data collected on this project were coded, transferred to the Federal Water Quality Administration Storet II Water Quality Data Sheets (Form No. GPO 902-791), and sent to the Robert S. Kerr Water Research Center, Ada, Oklahoma for storage in the Storet System. The code numbers assigned to the sampling stations are shown below:

Project Station Number	Storet II Station Code
1	360625009552300
2	360624009555200
3	360508009554100
4	360851009554300
5	360733009559600
6	361030009558220
7	360708009555100
8	361102009556020
9	361252009558430
10	360828009600030
11	361109009559070
12	361152009552070
13	360515009557530
14	360428009557290
15	360552009559050

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APPENDIX H

FORMAT OF DATA CARDS
USED
FOR COMPUTER ANALYSIS

This appendix gives the format of the data cards used for recording and storing all of the storm water quality data and other pertinent information collected and calculated on this project. These cards served as input data to many statistical computer programs used to analyze and evaluate the characteristics of storm water pollution.

All statistical analyses were performed utilizing an IBM 360 computer and the System/360 Scientific Subroutine Package--(360A-CM-03X) Version III. The reference document for these programs is IBM Application Program Manual No. H20-0205-3.

TABLE H-1

FORMAT OF DATA CARDS

Symbol	Item	Unit	Columns	Card No.
Y_1	Total coliform	thousands/100 ml	1- 6	
Y_2	Fecal coliform	number/100 ml	7-12	
Y_3	Fecal streptococcus	thousands/100 ml	13-18	
Y_4	BOD	mg/l	19-24	
Y_5	COD	mg/l	25-30	
Y_6	TOC	mg/l	31-36	
Y_7	Organic Kjeldahl nitrogen	mg/l	37-42	
Y_8	Total soluble orthophosphate	mg/l	43-48	
	Blank		49-63	
	Date		64-69	
	Event no.		70-71	
	Time		72-75	
	Test area no.		76-77	
	Composite or grab sample		78	
	Sample no.		79	
	Card no.		80	1
Y_9	Total solids	mg/l	1- 6	
Y_{10}	Dissolved solids	mg/l	7-12	
Y_{11}	Volatile dissolved solids	mg/l	13-18	
Y_{12}	Suspended solids	mg/l	19-24	
Y_{13}	Volatile suspended solids	mg/l	25-30	
Y_{14}	pH	dimensionless	31-36	
Y_{15}	Chloride	mg/l	37-42	
Y_{16}	Specific conductance	micromhos/cm	43-48	
	Blank		49-63	
	Date		64-69	
	Event no.		70-71	
	Time		72-75	
	Test area no.		76-77	
	Composite or grab sample		78	
	Sample no.		79	
	Card no.		80	2

TABLE H-1--Continued

Symbol	Item	Unit	Columns	Card No.
Z_1	Time since start	hr.	1- 6	
Z_2	Antecedent amount	in.	7-12	
Z_3	Antecedent average intensity	in. /hr.	13-18	
Z_4	Time since antecedent event	hr.	19-24	
Z_5	Amount of antecedent event	in.	25-30	
Z_6	Duration of antecedent event	hr.	31-36	
Z_7	Avg. intensity of antecedent event	in. /hr.	37-42	
Z_8	Antecedent prec. index (API)	in.	43-48	
	Blank		49-63	
	Date		64-69	
	Event no.		70-71	
	Time		72-75	
	Test area no.		76-77	
	Composite or grab sample		78	
	Sample no.		79	
	Card no.		80	3
X_1	Environmental Index (EI)	dimensionless	1- 6	
X_2	Housing Index (HI)	dimensionless	7-12	
X_3	Good housing	%	13-18	
X_4	Fair housing	%	19-24	
X_5	Poor housing	%	25-30	
X_6	Refuse	no. def. /acre	31-36	
X_7	Burners	no. def. /acre	37-42	
X_8	Rubble	no. def. /acre	43-48	
X_9	Lumber	no. def. /acre	49-54	
X_{10}	Old autos	no. def. /acre	55-60	
X_{11}	Poor sheds	no. def. /acre	61-66	
X_{12}	Total deficiencies	no. def. /acre	67-72	
	Blank		73-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	4

TABLE H-1--Continued

Symbol	Item	Unit	Columns	Card No.
X_{13}	Arterial streets	acres/acre	1- 6	
X_{14}	Arterial streets	miles/acre	7-12	
X_{15}	Other streets	acres/acre	13-18	
X_{16}	Other streets	miles/acre	19-24	
X_{17}	Residential density	people/res. acre	25-30	
X_{18}	Residential density	people/acre	31-36	
X_{19}	Main covered storm sewer	miles	37-42	
X_{20}	Covered sewer/ total length	ratio	43-48	
X_{21}	Arterial streets	%	49-54	
X_{22}	Other streets	%	55-60	
X_{23}	Residential land	%	61-66	
X_{24}	Commercial land	%	67-72	
	Blank		73-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	5
X_{25}	Industrial land	%	1- 6	
X_{26}	Institutional land	%	7-12	
X_{27}	Transportational land	%	13-18	
X_{28}	Open space	%	19-24	
X_{29}	Unused space	%	25-30	
X_{21}	Arterial streets	%	31-36	
X_{22}	Other streets	%	37-42	
X_{23}	Residential land	%	43-48	
X_{24}	Commercial land	%	49-54	
X_{17}	Residential density	people/res. acre	55-60	
X_{18}	Residential density	people/acre	61-66	
X_1	Environmental Index (EI)	dimensionless	67-72	
	Blank		73-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	6

TABLE H-1--Continued

Symbol	Item	Unit	Columns	Card No.
	All Items: Arith. Mean by Events			
M_1	Total coliform[a]	thousands/100 ml	1- 6	
M_2	Fecal coliform[a]	thousands/100 ml	7-12	
M_3	Fecal streptococcus[a]	thousands/100 ml	13-18	
M_4	BOD	mg/l	19-24	
M_5	COD	mg/l	25-30	
M_6	TOC	mg/l	31-36	
M_7	Organic Kjeldahl nitrogen	mg/l	37-42	
M_8	Total soluble orthophosphate	mg/l	43-48	
	Blank		49-66	
D_{10}	Relief number	dimensionless	67-72	
	Blank		73-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	7
	All Items: Arith. Mean by Events			
M_9	Total solids	mg/l	1- 6	
M_{10}	Dissolved solids	mg/l	7-12	
M_{11}	Volatile dissolved solids	mg/l	13-18	
M_{12}	Suspended solids	mg/l	19-24	
M_{13}	Volatile suspended solids	mg/l	25-30	
M_{14}	pH	dimensionless	31-36	
M_{15}	Chloride	mg/l	37-42	
M_{16}	Specific conductance	micromhos/cm	43-48	
	Blank		49-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	8

[a] Geometric mean by events

TABLE H-1--Continued

Symbol	Item	Unit	Columns	Card No.
D_1	Total area	acres	1- 6	
D_2	Length of main stream	feet	7-12	
D_3	Length to center of area	feet	13-18	
D_4	Fall of drainage area	feet	19-24	
D_5	Average main channel slope	feet/foot	25-30	
D_6	Average land slope	%	31-36	
D_7	Impervious cover	%	37-42	
X_{30}	Open space + institutional land	%	43-48	
X_{31}	Open space + transportational land	%	49-54	
X_{25}	Industrial land	%	55-60	
D_8	Geometry number (G)	dimensionless	61-66	
D_9	Form factor (FF)	dimensionless	67-72	
	Blank		73-75	
	Test area no.		76-77	
	Blank		78-79	
	Card no.		80	9
L_1	BOD loading	lb./day/mile of street	1- 6	
L_2	COD loading	lb./day/mile of street	7-12	
L_3	Total solids loading	lb./day/mile of street	13-18	
L_4	Organic Kjeldahl nitrogen loading	lb./day/mile of street	19-24	
L_5	Soluble orthophosphate loading	lb./day/mile of street	25-30	
L_6	BOD loading	lb./acre/year	31-36	
L_7	COD loading	lb./acre/year	37-42	
L_8	Total solids loading	lb./acre/year	43-48	
L_9	Organic Kjeldahl nitrogen loading	lb./acre/year	49-54	
L_{10}	Soluble orthophosphate loading	lb./acre/year	55-60	
	Blank		61-75	
	Test area no.		76-77	
	Card no.		78-80	10

APPENDIX I

STREET CLEANING OPERATIONS IN TULSA

Large portions of the typical urban area are devoted to street and expressway systems. Since urban storm water runoff reaches the drainage system and thus the receiving streams via the road system, no report on storm water pollution would be complete without investigating and analyzing the street cleaning operations. The following pages describe the city street cleaning and drainage maintenance operations. Also included are data showing the volumes of street refuse collected and the various cost functions which have been assigned concerning the street cleaning operations in Tulsa.

Street Cleaning

In any investigation of urban storm water pollution, consideration has to be given to the litter accumulated in the streets. As pointed out in the 1969 Federal Water Pollution Control Administration publication, "Water Pollution Aspects of Urban Runoff," the actual amount of litter on the street at any one time is largely dependent upon the frequency and effectiveness of the street cleaning operations. Also, the report indicates that the amount and nature of street litter is found to vary with land use, population, traffic flow, and other indigenous factors.

In Tulsa, the street cleaning is conducted by the Street Maintenance Department. Within this department, there are five main divisions: (1) street cleaning, (2) storm sewers, (3) paved streets, (4) unpaved streets, and (5) demolition and forestry. All divisions of this department are of significance to this study.

Street Cleaning Section - The city is divided into eight street cleaning districts, which vary in size according to the number of streets in each area. The district characteristics and locations are shown in Figure I-1 and Table I-1. The downtown area (District No. 1) is swept and flushed nightly except Saturdays. Arterial streets are swept and flushed a minimum of once weekly, more often if required. Residential streets are swept approximately six times per year. There are approximately 1,071 miles of paved, and 576 miles of unpaved, streets and alleys in Tulsa. By the city's definition, an unpaved street (or alley) is any dirt,

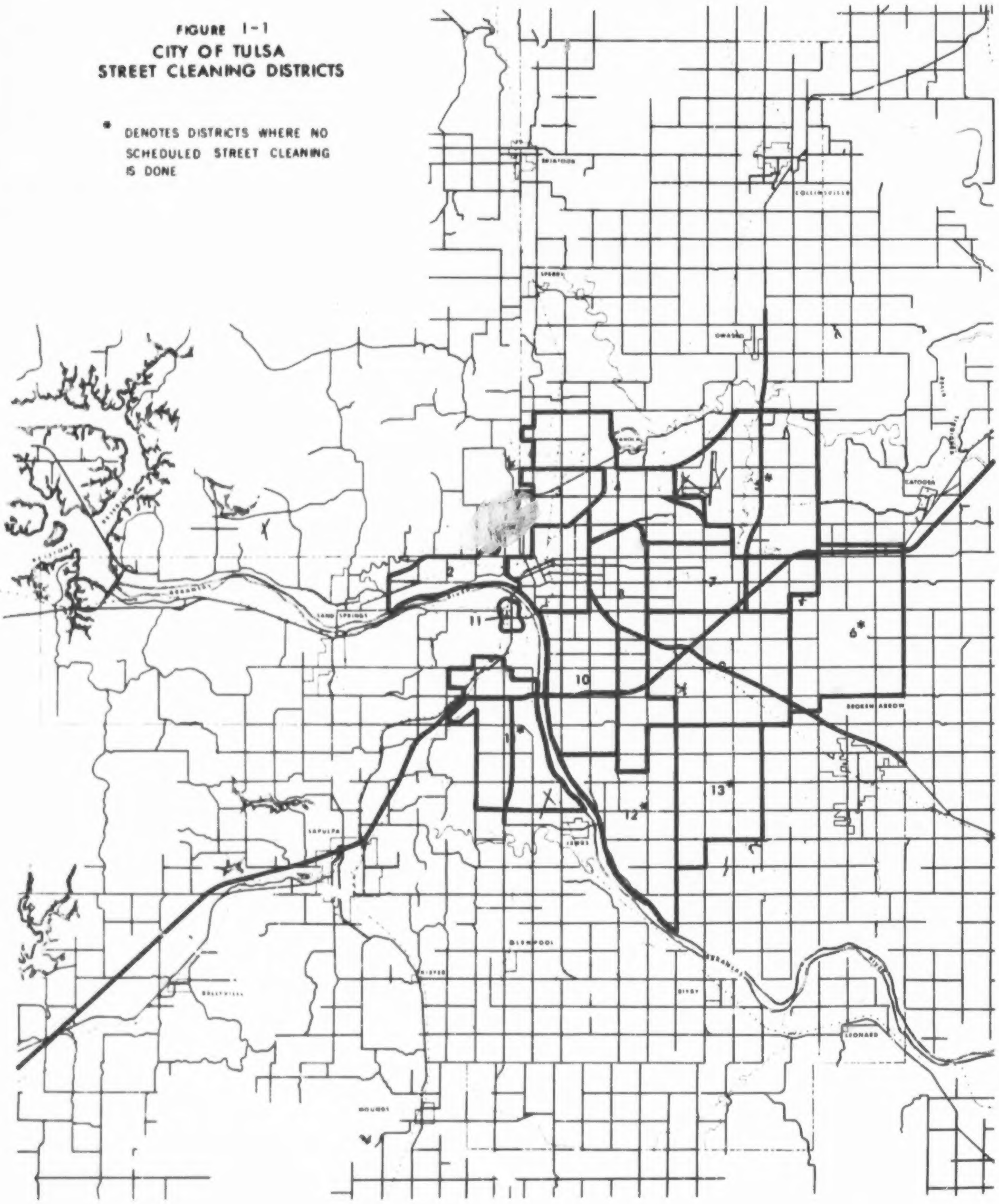

FIGURE 1-1
CITY OF TULSA
STREET CLEANING DISTRICTS

* DENOTES DISTRICTS WHERE NO SCHEDULED STREET CLEANING IS DONE

SKIATOOK
COLLINSVILLE
SPERRY
OWASSO
CATOOSA
2
SAND SPRINGS
11
7
5*
6*
10
BROKEN ARROW
1*
12*
13*
SAPULPA
JENKS
GLENPOOL
KIEFER
BIXBY
LEONARD
MOUNDS

TABLE I-1

CITY OF TULSA
STREET SWEEPING DISTRICTS

District Number	District Name	No. of Curb Blocks[a]	Sweeping Frequency
1	Downtown	3200	Each night except Saturday
2	Northwest	3744	10 weeks
3.	North Central	1322	5-6 weeks
4	Northeast	2820	8 weeks
5	Far Northeast	n. d.	Not scheduled
6	Far East	n. d.	Not scheduled
7	East No. 2	3736	10 weeks
8	East No. 1	3978	11 weeks
9	Southeast No. 1	3628	9 weeks
10	Southeast No. 2	3384	10 weeks
11	Southwest	n. d.	Not scheduled
12	Far South	n. d.	Not scheduled
13	Far Southeast	n. d.	Not scheduled

[a] n. d. =no data.

rock, oiled, or asphalted street having no concrete base, curbs, or gutters. An average of 3, 700 curb miles of streets is cleaned per month. Since curb miles represent both sides of a street, the preceding figure is reduced to 1850 miles of streets per month. The average monthly cleaning is 80% for downtown streets and 20% for residential areas because the downtown area is swept nightly, and arterial streets weekly.

The Street Cleaning Section is divided into two 30-man shifts (day and night). A sweeping crew normally consists of one sweeper operator, one flusher operator, one dump truck operator, and two laborers.

During the past year, the city started replacing its old sweepers with new machines having added features. Incorporated in the new models are dirt and trash hoppers capable of unloading into trucks or other containers. This new type of machine will cut down the operation cost of the street cleaning department.

This section also removes debris, underbrush, and trees from the open channels. With its appropriate equipment, the section performs the major portion of cleaning all streets of debris after storms. There are approximately 500 miles of open drainage channels in Tulsa at the present time.

Although this section's major function is maintenance of unpaved streets, considerable time and effort are spent on indirectly controlling storm water pollution through cleaning and maintenance of the open drainage ditches. Since all of the cost of this section is combined, no effort was made to determine the cost for cleaning and maintenance of open drainage.

Forestry and Demolition - This section's responsibilities are weed control and removal of debris, trees, and underbrush from city property. A new function of this department is the demolition of dilapidated structures condemned by the Health Department and City Commission. This new function will clear areas of unwanted dilapidated structures, thereby indirectly helping to control urban storm water pollution.

Snow and Ice Control - The city uses both salt and sand for snow and ice control. Salt is used mainly in the downtown areas and on arterial streets. Sand is used primarily at intersections in outlying areas. Due to Tulsa's geographical location, these practices are utilized infrequently.

The amount of salt used during the winter months of 1968-1969 in Tulsa was approximately 90,000 pounds. This compares with approximately 530,000 pounds used during the winter months of 1967-1968. The much larger amount used during 1967-1968 was due to the unusually heavy amount (11.8 in.) of snow received in March 1968. Based on thirty years of records at the Tulsa International Airport, the yearly mean snowfall is 9.4 inches. The amount of salt applied to the streets and the amount of snow recorded during the past two fiscal years are shown below:

Year	Snow (in.)	Salt Applied (lb.)
FY 1967-68	17.0	530,000
FY 1968-69	8.0	90,000

TABLE I-2

MONTHLY STREET CLEANING OPERATIONS FOR FISCAL YEAR 1967-1968

Month	Components of Street Litter In Cubic Yards						Water Used By Flushers MG	Number Of Curb Blocks Cleaned	Estimated Average cu. yd. /block
	Dirt	Trash	Limb	Leaves and Grass	Other[a]	Total			
July	498	2925	120	0	231	3774	3.7	53,000	0.071
Aug.	411	3840	321	15	129	4716	5.0	53,000	0.089
Sept.	57	2041	168	30	234	2550	4.0	45,000	0.057
Oct.	381	3135	168	1035	258	4977	5.2	53,000	0.094
Nov.	108	2304	111	2142	375	5040	2.9	39,000	0.129
Dec.	129	885	174	1458	237	2883	1.7	33,000	0.087
Jan.	369	2184	87	108	285	3033	2.8	36,000	0.084
Feb.	576	1986	69	72	408	3111	2.5	38,000	0.082
Mar.	366	2085	606	72	87	3216	3.0	35,000	0.092
Apr.	474	2367	384	90	432	3747	4.3	39,000	0.096
May	567	3582	447	33	252	4881	4.2	53,000	0.092
June	405	2838	393	3	204	3843	3.7	48,000	0.080
Total	4341	30,192	3048	5058	3132	45,771	43.0	525,000	

[a] This category includes sand, gravel, rock, and other street litter not included in the other categories.

TABLE I-3

MONTHLY STREET CLEANING OPERATIONS FOR FISCAL YEAR 1968-1969

Month	Components of Street Litter In Cubic Yards						Water Used By Flushers MG	Number Of Curb Blocks Cleaned	Estimated Average cu. yd. /block
	Dirt	Trash	Limb	Leaves and Grass	Other[a]	Total			
July	810	3234	378	0	168	4590	3.9	50,000	0.092
Aug.	303	2946	363	0	255	3867	4.2	46,000	0.084
Sept.	174	3189	288	0	1143	4794	3.0	45,000	0.106
Oct.	66	4083	273	414	264	5100	3.6	49,000	0.104
Nov.	105	1473	225	1428	264	3495	2.0	23,000	0.152
Dec.	60	1107	222	2283	3	3675	0.9	31,000	0.118
Jan.	39	3531	183	510	390	4653	2.6	51,000	0.091
Feb.	375	1797	51	102	324	2649	2.9	46,000	0.058
Mar.	471	2736	78	129	258	3672	3.2	48,000	0.076
Apr.	306	3288	174	99	411	4278	4.3	57,000	0.075
May	156	2199	216	0	186	2757	3.9	48,000	0.057
June	303	2034	330	6	222	2895	4.7	46,000	0.063
Total	3168	31,617	2781	4971	3888	46,425	39.2	494,000	

[a] This category includes sand, gravel, rock, and other street litter not included in the other categories.

A study of the Street Department's monthly and annual reports provided information on the amounts and components of street litter collected in Tulsa.

Tables I-2 and I-3 show the monthly volumes, components, and number of curb blocks cleaned in Tulsa for FY 1967-68 and FY 1968-69.

The reported yearly average volumes of street litter collected in the residential and commercial areas are:

Residential areas	16 to 18 cu. yd. /sq. mi.
Commercial areas	14 to 16 cu. yd. /sq. mi.

The average yearly weights per square mile are:

Residential areas	4 tons/sq. mi.
Commercial areas	4. 5 tons/sq. mi.

The greater tonnage and lower volume collected in the commercial areas are attributed to a larger collection of rock and sand on major thoroughfares and in the downtown area. This could result from the greater effort devoted to sanding operations in the downtown area during snow or ice storms.

The average yearly cost for cleaning the streets in Tulsa is approximately $447, 000. 00. This average is based on the expenditures for FY 1967-68 and FY 1968-69. The cost includes wages, material, and equipment. It does not include cost incurred for administration or overhead. Various yearly cost functions are:

(1) $ 1. 38 per capita
(2) $420. 00 per mile of paved street
(3) $ 0. 88 per curb block cleaned
(4) $ 98. 00 per cubic yard of street litter collected

Storm Sewer Section - The storm sewer division maintains approximately 330 miles of storm sewer which varies in size from 12 inch diameter pipes to 15 foot semielliptical sections. The average length of storm sewer lines cleaned per year is 12, 000 feet (2. 27 miles).

This division is also responsible for cleaning approximately 22, 000 catch basins. The catch basins, all located in the older sections of the city, are cleaned on an "as needed" basis. The average number cleaned per year is 2, 100. The volume of dirt and trash removed

TABLE I-4

STORM SEWER CLEANING AND MAINTENANCE FOR
FISCAL YEAR 1967-1968 AND FISCAL YEAR 1968-1969

Month	Catch Basins Cleaned	FY 1967-68 Storm Sewer Cleaned (Feet)	Cubic Yards of Dirt and Trash	Month	Catch Basins Cleaned	FY 1968-69 Storm Sewer Cleaned (Feet)	Cubic Yards of Dirt and Trash
July	194	20	30	July	98	795	0
Aug.	268	220	87	Aug.	63	785	9
Sept.	117	675	6	Sept.	113	1, 191	9
Oct.	159	640	9	Oct.	83	223	0
Nov.	227	815	24	Nov.	101	1, 118	0
Dec.	131	775	21	Dec.	163	1, 075	81
Jan.	168	845	12	Jan.	245	1, 085	45
Feb.	221	877	24	Feb.	292	1, 290	42
Mar.	364	1, 060	24	Mar.	155	1, 205	3
Apr.	267	962	84	Apr.	182	1, 144	18
May	112	895	30	May	220	1, 405	24
June	72	945	18	June	118	1, 475	12
Total	2, 300	8, 729	369	Total	1, 833	12, 791	243

from the catch basins in FY 1968-69 was 243 cubic yards. The older catch basins are being replaced with a design that is "self-cleaning." The new type has a direct connection to the storm sewer line and has no holding capacity for solids or runoff water. Catch basins are not included in the street design of Tulsa's newer developments.

Although the main function of this section is to keep storm sewers, manholes, and catch basins free of accumulated debris, this section also installs stud-outs to drain low areas. During and after heavy rains, pumping operations are carried on in low areas and dead-end sewers.

The total man-hours worked by this division in FY 1967-68 and FY 1968-69 were 7,582 and 6,944, respectively. The cleaning and maintenance activities for these two fiscal years are shown in Table I-4. The total cost of operation (including wages, material, and equipment) was approximately $21,000.00 in FY 1967-68 and $22,000 in FY 1968-69. The yearly cost functions are:

(1) $ 0.07 per capita
(2) $10.24 per catch basin cleaned
(3) $63.42 per cubic yard of catch basin solids removed

The above cost functions are somewhat in error because there was no way of breaking down the wages and equipment for the various work items of the section. Therefore, the cost per catch basin cleaned and the cost per cubic yard of catch basin solids are extremely high because the other work items (storm sewer cleaning, installation of stud-outs, and pumping of low areas) are included in these figures.

Paved Street Section - The major functions of this section are: repairs on paved streets, minor repairs on structures, replacement of paving cuts, and drainage channel relocation. Inspection of the Street Department's monthly reports indicates that on occasion this section performs some street cleaning. Since the amount of street litter picked up is very small, no cost estimates were made.

Unpaved Street Section - This section's main function is to keep all unpaved streets and alleys open for traffic. The major portion of this work is accomplished through grading, ditching, and filling the bad places with crushed rock. There are approximately 575 miles of unpaved streets and alleys in the city.

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APPENDIX J

CITY OF TULSA'S MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT DATA

The information in this appendix was compiled to provide the pollution loadings to the receiving streams from the four treatment plants serving Tulsa. These data were then compared with the storm water pollution loadings from the urban area; results of such comparisons are given in Section 9.

The locations and general characteristics of the treatment plants are shown in Figure J-1 and Table J-1. Tables J-2 and J-3 give the monthly average daily flows for the years 1967 and 1968, along with the associated total flows to the Arkansas River and Bird Creek.

Average pollutant concentrations for BOD, COD, suspended solids, organic Kjeldahl nitrogen, and soluble orthophosphate have been listed in Table J-4. There is, as one might expect, considerable variation in these concentrations, as shown in the cumulative frequency distributions for BOD and suspended solids in Table J-5. These frequency distributions are related to the efficiencies illustrated in Table J-6.

Finally, Table J-7 contains the estimated average pollution loadings calculated from the data already given. For comparison of these results with the quality of storm water runoff, reference should be made to Table 46 in Section 9.

FIGURE J-1
SEWAGE TREATMENT FACILITIES
TULSA, OKLAHOMA

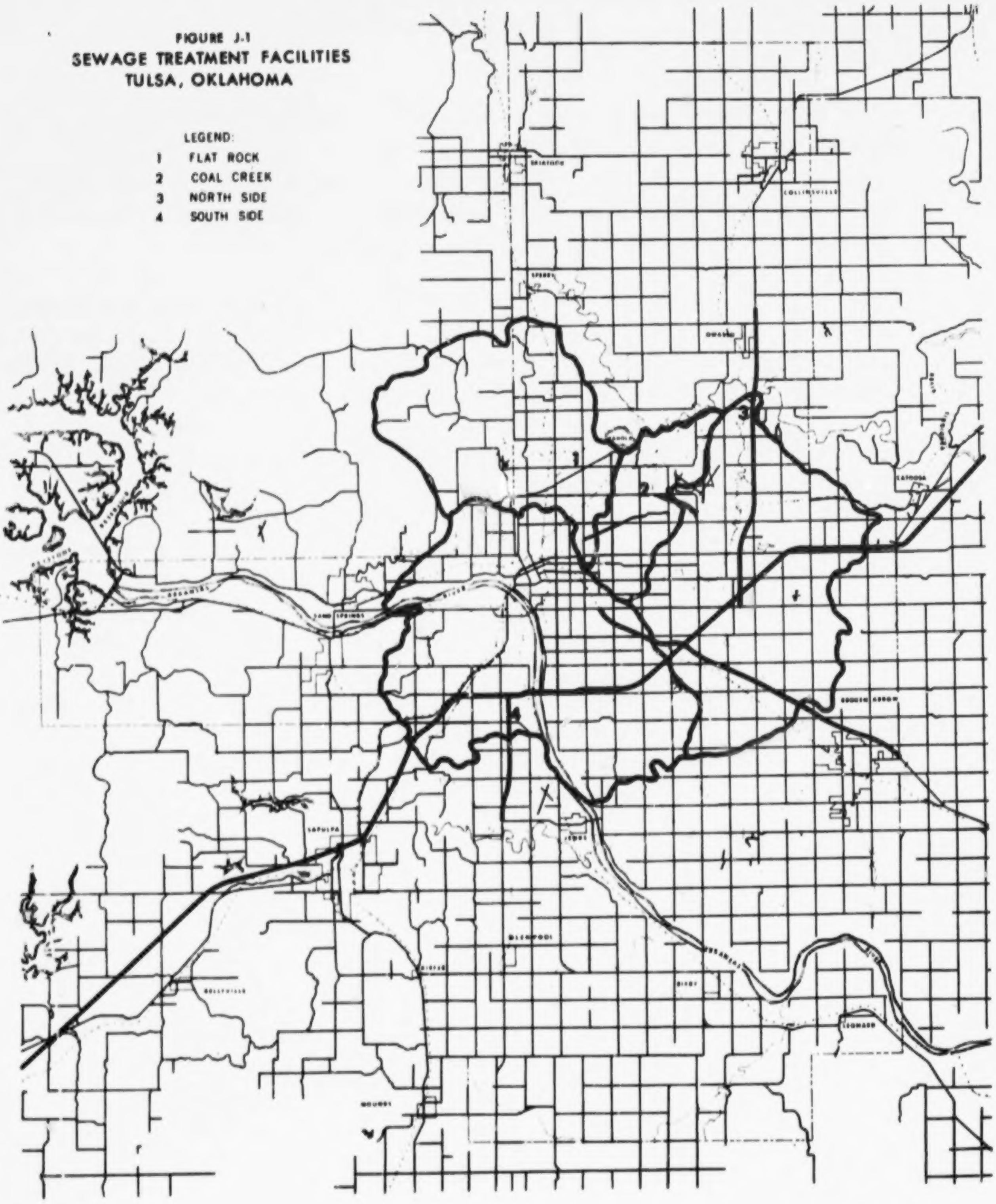
LEGEND:
1 FLAT ROCK
2 COAL CREEK
3 NORTH SIDE
4 SOUTH SIDE
1
2
3
4
SKIATOOK
COLLINSVILLE
SPERRY
OWASSO
CATOOSA
SAND SPRINGS
ARKANSAS RIVER
BROKEN ARROW
SAPULPA
JENKS
GLENPOOL
BIXBY
LEONARD
KELLYVILLE
MOUNDS
KIEFER

TABLE J-1

CHARACTERISTICS OF TULSA'S FOUR SEWAGE TREATMENT PLANTS

Treatment Plant	Population Served	Capacity	Type of Removal
Flat Rock	57, 100	4 mgd	Primary and secondary--secondary treatment accomplished by contact stabilization
Coal Creek	52, 950	4 mgd	Primary and secondary--secondary treatment accomplished by trickling filter processes
North Side	57, 100	11 mgd	Primary and secondary--secondary treatment accomplished by trickling filter processes
South Side	156, 590	21 mgd	Primary

TABLE J-2

MONTHLY AVERAGE DAILY FLOWS[a]
1967

Month	Average Daily Flow (mgd) Flat Rock	Coal Creek	North Side	Subtotal[b]	South Side[c]	Total[d]
Jan.	4.5	2.3	5.9	12.7	13.0	25.7
Feb.	4.5	2.2	6.3	13.0	13.1	26.1
Mar.	4.5	2.4	6.1	13.0	13.4	26.4
Apr.	5.0	3.0	7.2	15.2	14.0	29.2
May	5.2	3.5	8.2	16.9	15.1	32.0
June	5.3	3.4	8.7	17.4	15.9	33.3
July	5.4	3.6	7.4	16.4	16.6	33.0
Aug.	5.1	3.1	8.2	16.4	15.1	31.5
Sept.	5.4	3.2	7.9	16.5	14.3	30.8
Oct.	4.8	2.9	7.4	15.1	13.7	28.8
Nov.	5.4	3.2	8.4	17.0	14.8	31.8
Dec.	5.1	3.0	7.5	15.6	14.1	29.7
Average	5.0	3.0	7.4	15.4	14.4	29.8

[a] Based on unpublished data from the Tulsa Water and Sewer Department
[b] Total to Bird Creek
[c] Total to Arkansas River
[d] Total from City of Tulsa

TABLE J-3

MONTHLY AVERAGE DAILY FLOWS[a]
1968

Month	Average Daily Flow (mgd) Flat Rock	Coal Creek	North Side	Subtotal[b]	South Side[c]	Total[d]
Jan.	5.8	3.1	6.9	15.8	14.1	29.9
Feb.	6.2	4.0	6.0	16.2	17.0	33.2
Mar.	5.6	4.7	6.6	16.9	17.7	34.6
Apr.	7.2	5.6	8.0	20.8	16.1	36.9
May	7.0	4.0	7.1	18.1	16.8	34.9
June	6.5	3.9	7.2	17.6	14.8	32.4
July	5.5	3.2	7.7	16.4	15.2	31.6
Aug.	5.5	3.0	8.2	16.7	15.0	31.7
Sept.	5.2	3.0	7.3	15.5	14.3	29.8
Oct.	5.2	3.0	8.3	16.5	13.3	29.8
Nov.	5.8	3.4	7.9	17.1	11.5	28.5
Dec.	5.4	3.6	7.8	16.8	10.4	27.2
Average	5.9	3.5	7.4	16.8	14.7	31.5

[a] Based on unpublished data from the Tulsa Water and Sewer Department
[b] Total to Bird Creek
[c] Total to Arkansas River
[d] Total from City of Tulsa

TABLE J-4

AVERAGE POLLUTION PARAMETER CONCENTRATIONS FROM CITY OF TULSA'S SEWAGE TREATMENT PLANTS

	Average Concentration (mg/l)				
Treatment Plant	BOD[a]	COD[a]	Suspended Solids[a]	Organic Kjeldahl Nitrogen[b]	Soluble Orthophosphate[a]
Flat Rock	55	272	93	2.0	45
Coal Creek	34	265	42	4.3	40
North Side	16	72	21	3.9	58
South Side	120	340	92	2.4	33

[a] Average monthly values for 1968 (Unpublished data, City of Tulsa, Water and Sewer Department).

[b] Source: U. S. Department of HEW, PHS, *Preliminary Studies Arkansas River and Tributaries--Tulsa to Muskogee, Oklahoma*, February, 1966.

TABLE J-5

QUALITY OF EFFLUENT FROM TULSA'S MUNICIPAL SEWAGE TREATMENT PLANTS[a]

Period of Time %	Probable Concentration (mg/l) Flat Rock	Coal Creek	North Side	Composite	South Side
Biochemical Oxygen Demand					
10	28	21	10	11	126
20	35	29	12	13	138
30	42	35	16	18	151
40	51	39	17	23	158
50	66	44	18	32	165
60	77	50	19	41	174
70	86	60	20	53	181
80	98	70	22	74	191
90	113	83	23	93	202
Suspended Solids					
10	76	24	10	17	69
20	90	31	16	23	81
30	100	37	18	29	88
40	109	43	21	35	93
50	116	48	24	47	99
60	128	53	27	65	106
70	138	60	30	87	111
80	151	67	33	111	117
90	178	75	38	138	125

[a] Source: Wheeler and Associates, *Report on Sewage Collection and Treatment Facilities for Tulsa, Oklahoma,* 1967, p. 65.

TABLE J-6

EFFICIENCY OF REMOVAL OF TULSA'S MUNICIPAL SEWAGE TREATMENT PLANTS[a]

Period of Time %	Probable Percentage Removal Flat Rock	Coal Creek	North Side	Composite	South Side
Biochemical Oxygen Demand					
90	18	61	87	45	12
80	32	65	88	60	20
70	47	68	89	68	23
60	58	73	90	70	25
50	60	75	90	79	28
40	65	78	91	84	30
30	71	80	91	87	33
20	75	82	92	89	37
10	79	86	93	91	41
Suspended Solids					
90	16	63	86	28	38
80	22	68	88	45	47
70	30	72	89	59	53
60	37	75	90	69	56
50	41	77	90	78	58
40	46	80	91	83	61
30	52	82	92	86	63
20	57	84	93	89	65
10	62	87	94	91	68

[a] Source: Wheeler and Associates, Report on Sewage Collection and Treatment Facilities for Tulsa, Oklahoma, 1967, p. 64.

TABLE J-7

ESTIMATED AVERAGE DAILY LOADS TO RECEIVING STREAMS FROM THE CITY OF TULSA'S FOUR SEWAGE TREATMENT PLANTS

		Average Daily Load (lbs. /day)				
Treatment Plant	Receiving Stream	BOD	COD	Suspended Solids	Organic Kjeldahl Nitrogen	Soluble Orthophosphate
Flat Rock	Bird Creek	2,700	13,400	4,600	100	2,220
Coal Creek	Bird Creek	980	7,650	1,200	130	1,170
North Side	Bird Creek	990	4,450	1,300	240	3,580
Subtotal	Bird Creek	4,670	25,500	7,100	470	6,970
South Side	Arkansas River	14,700	41,680	11,300	290	4,050
Total		19,370	67,180	18,400	760	11,020

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APPENDIX K

REGRESSION EQUATIONS

This appendix contains a selection of 263 of the univariate and multivariate regression equations developed during the course of the study. The legend for the dependent and independent variables is given in Table K-1. The equations themselves, along with their corresponding correlation coefficients and F-values, are tabulated in Tables K-2 through K-7.

Tables K-2 and K-3 are both concerned with precipitation variables. In Table K-2 are shown equations developed using data for all test samples taken from all 15 test areas. Multiple regression equations listed in Table K-3, on the other hand, were derived using BOD data for only the samples which were collected on the rising limb of the runoff hydrograph. Correlation coefficients for a number of additional regression equations of this type are shown in Table 62 in Section 10.

Whereas Tables K-2 and K-3 deal with pollution parameter concentrations at particular times during individual precipitation events, the last four tables in this appendix are concerned with relating average pollutant concentrations in storm water runoff to environmental, drainage, and land use characteristics. The best univariate land use equations for all test areas are shown in Table K-4. Table K-5 illustrates a selection of the best univariate and multiple regression equations for predictor variables common to both commercial and residential areas (Test Areas No. 1, 12, and 14 have been omitted). Tables K-6 and K-7 give, respectively, regression equations for residential test areas and for commercial and industrial test areas.

For more complete explanations of the data presented in this appendix, and for a description of the statistical methods used, reference should be made to Section 10 of this report.

TABLE K-1

DEPENDENT AND INDEPENDENT VARIABLES USED IN REGRESSION ANALYSIS

Symbol	Item	Unit
D_1	Total area	acres
D_2	Length of main stream	feet
D_3	Length to center of area	feet
D_4	Fall of drainage area	feet
D_6	Average land slope	%
D_9	Form factor	dimensionless
M_1	Total coliform geometric mean[a]	thousands/100 ml
M_2	Fecal coliform geometric mean	thousands/100 ml
M_3	Fecal streptococcus geometric mean	thousands/100 ml
M_4	Mean[b] BOD	mg/l
M_5	Mean COD	mg/l
M_6	Mean TOC	mg/l
M_7	Mean organic Kjeldahl nitrogen	mg/l
M_8	Mean soluble orthophosphate	mg/l
M_9	Mean total solids	mg/l
M_{10}	Mean dissolved solids	mg/l
M_{12}	Mean suspended solids	mg/l
M_{16}	Mean specific conductance	micromhos/cm
X_1	Environmental Index (EI)	dimensionless
X_{13}	Arterial streets	acres/acre
X_{14}	Arterial streets	miles/acre
X_{15}	Other streets	acres/acre
X_{16}	Other streets	miles/acre
X_{17}	Residential density	people/res. acre
X_{18}	Residential density	people/acre
X_{19}	Main covered storm sewer	miles
X_{20}	Covered sewer/total length[c]	ratio
X_{21}	Arterial streets	%
X_{22}	Other streets	%
X_{24}	Commercial land	%
X_{25}	Industrial land	%
X_{29}	Unused space	%

TABLE K-1--Continued

Symbol	Item	Unit
Y_1	Total coliform	thousands/100 ml
Y_2	Fecal coliform	number/100 ml
Y_3	Fecal streptococcus	thousands/100 ml
Y_4	BOD	mg/l
Y_5	COD	mg/l
Y_9	Total solids	mg/l
Z_1	Time since start	hours
Z_2	Antecedent amount	inches
Z_3	Antecedent average intensity	inches/hour
Z_4	Time since antecedent event	hours
Z_5	Amount of antecedent event	inches
Z_7	Average intensity of antecedent event	inches/hour

[a] For bacterial parameters, the geometric means are calculated from the arithmetic averages of each event.

[b] Arithmetic mean by events.

[c] See Glossary (Section 14) for a definition of the covered sewer/total length ratio.

TABLE K-2

REGRESSION EQUATIONS
POLLUTIONAL PARAMETER CONCENTRATIONS VS. PRECIPITATION VARIABLES

Regression Equation[a]	Correlation (R)	F-Value[b]	Equation Number
Total Coliform (Thousands/100 ml)			
$\ln Y_1 = 4.5125 - 0.1667 (Z_1)$	-0.167	11.13**	K-1
$\ln Y_1 = 4.4209 - 1.0553 (Z_2)$	-0.151	9.08**	K-2
$\ln Y_1 = 3.6591 + 0.7748 (Z_3)$	0.056	1.22	K-3
$\ln Y_1 = 4.0465 - 0.0011 (Z_4)$	-0.078	2.35	K-4
$\ln Y_1 = 4.2364 - 0.6697 (Z_5)$	-0.122	5.82*	K-5
$\ln Y_1 = 3.3093 + 2.8925 (Z_7)$	0.135	7.15**	K-6
$\ln Y_1 = 4.5157 - 0.0921 (Z_1) - 0.7517 (Z_2) + 0.6174 (Z_3)$	0.185	4.55**	K-7
$\ln Y_1 = 4.7559 - 0.1017 (Z_1) - 0.6506 (Z_2) - 0.00063 (Z_4)$	0.186	4.62**	K-8
$\ln Y_1 = 5.2598 - 0.0853 (Z_1) - 0.9638 (Z_2) - 0.8297 (Z_5)$	0.232	7.27**	K-9
$\ln Y_1 = 3.8498 - 0.00039 (Z_4) - 0.7950 (Z_5) + 3.2111 (Z_7)$	0.200	5.33**	K-10
Fecal Coliform (Number/100 ml)			
$\ln Y_2 = 3.0496 - 0.2022 (Z_1)$	-0.093	3.12	K-11
$\ln Y_2 = 1.4867 + 1.1215 (Z_2)$	0.076	2.05	K-12
$\ln Y_2 = 1.7006 + 2.3628 (Z_3)$	0.086	2.62	K-13
$\ln Y_2 = 3.6669 - 0.0064 (Z_4)$	-0.208	16.07**	K-14
$\ln Y_2 = 2.2287 - 0.1047 (Z_5)$	-0.009	0.03	K-15
$\ln Y_2 = -0.0170 + 13,6623 (Z_7)$	0.295	33.95**	K-16
$\ln Y_2 = 2.4327 - 0.4498 (Z_1) + 2.8966 (Z_2) - 0.2350 (Z_3)$	0.183	4.08**	K-17

TABLE K-2--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
$\ln Y_2 = 3.2934 - 0.2840\,(Z_1) + 2.2461\,(Z_2) - 0.0053\,(Z_4)$	0.244	7.44**	K-18
$\ln Y_2 = 1.9157 - 0.4689\,(Z_1) + 3.1576\,(Z_2) + 0.6380\,(Z_5)$	0.189	4.38**	K-19
$\ln Y_2 = 1.5072 - 0.0039\,(Z_4) - 0.6503\,(Z_5) + 12.3412\,(Z_7)$	0.324	13.88**	K-20
Fecal Streptococcus (Thousands/100 ml)			
$\ln Y_3 = 2.4938 - 0.3757\,(Z_1)$	-0.318	48.88**	K-21
$\ln Y_3 = 1.1485 - 0.4251\,(Z_2)$	-0.051	1.14	K-22
$\ln Y_3 = 0.4574 + 2.3032\,(Z_3)$	0.149	9.91**	K-23
$\ln Y_3 = 2.0997 - 0.0053\,(Z_4)$	-0.321	49.91**	K-24
$\ln Y_3 = 0.7375 + 0.2506\,(Z_5)$	0.039	0.65	K-25
$\ln Y_3 = 0.2525 + 3.7180\,(Z_7)$	0.147	9.57**	K-26
$\ln Y_3 = 2.2075 - 0.5109\,(Z_1) + 1.5954\,(Z_2) - 0.3832\,(Z_3)$	0.352	20.40**	K-27
$\ln Y_3 = 2.7615 - 0.3901\,(Z_1) + 1.1460\,(Z_2) - 0.0039\,(Z_4)$	0.416	30.21**	K-28
$\ln Y_3 = 1.6878 - 0.5137\,(Z_1) + 1.7319\,(Z_2) + 0.5837\,(Z_5)$	0.362	21.75**	K-29
$\ln Y_3 = 1.6891 - 0.0051\,(Z_4) + 0.2647\,(Z_5) + 1.1073\,(Z_7)$	0.327	17.28**	K-30
BOD (mg/l)			
$\ln Y_4 = 2.3731 - 0.1264\,(Z_1)$	-0.126	6.76**	K-31
$\ln Y_4 = 2.4774 - 0.5125\,(Z_2)$	-0.210	19.13**	K-32
$\ln Y_4 = 2.3156 - 0.7452\,(Z_3)$	-0.149	9.42**	K-33
$\ln Y_4 = 2.2466 - 0.0003\,(Z_4)$	-0.060	1.51	K-34
$\ln Y_4 = 2.3351 - 0.2453\,(Z_5)$	-0.123	6.36*	K-35
$\ln Y_4 = 2.2143 - 0.2045\,(Z_7)$	-0.027	0.30	K-36
$\ln Y_4 = 2.6679 - 0.0408\,(Z_1) - 0.2790\,(Z_2) - 0.8185\,(Z_3)$	0.251	9.25**	K-37

TABLE K-2--Continued

Regression Equation	Correlation (R)	F Value	Equation Number
$\ln Y_4 = 2.5293 + 0.0018 (Z_1) - 0.5139 (Z_2) - 0.00026 (Z_4)$	0.216	6.75**	K-38
$\ln Y_4 = 2.7531 + 0.0086 (Z_1) - 0.6484 (Z_2) - 0.3674 (Z_5)$	0.274	11.21**	K-39
$\ln Y_4 = 2.4310 - 0.00033 (Z_4) - 0.2348 (Z_5) - 0.1692 (Z_7)$	0.138	2.67**	K-40
COD (mg/l)			
$\ln Y_5 = 4.5031 - 0.0391 (Z_1)$	-0.176	11.57**	K-41
$\ln Y_5 = 4.5138 - 0.3046 (Z_2)$	-0.199	14.91**	K-42
$\ln Y_5 = 4.3440 - 0.0434 (Z_3)$	-0.015	0.08	K-43
$\ln Y_5 = 4.3600 - 0.0001 (Z_4)$	-0.034	0.41	K-44
$\ln Y_5 = 4.2975 + 0.0618 (Z_5)$	0.050	0.90	K-45
$\ln Y_5 = 4.3649 - 0.1789 (Z_7)$	-0.037	0.50	K-46
$\ln Y_5 = 4.5757 - 0.0246 (Z_1) - 0.2001 (Z_2) - 0.0900 (Z_3)$	0.215	5.78**	K-47
$\ln Y_5 = 4.5559 - 0.0201 (Z_1) - 0.2247 (Z_2) - 0.00001 (Z_4)$	0.213	5.69**	K-48
$\ln Y_5 = 4.5339 - 0.0218 (Z_1) - 0.2101 (Z_2) + 0.0292 (Z_5)$	0.214	5.75**	K-49
$\ln Y_5 = 4.3750 - 0.00017 (Z_4) + 0.0798 (Z_5) - 0.3015 (Z_7)$	0.086	0.89	K-50
Total Solids (mg/l)			
$\ln Y_9 = 5.8313 - 0.0168 (Z_1)$	-0.057	1.33	K-51
$\ln Y_9 = 5.7428 + 0.0275 (Z_2)$	0.014	0.07	K-52
$\ln Y_9 = 5.6876 + 0.3788 (Z_3)$	0.097	3.85*	K-53
$\ln Y_9 = 5.7769 - 0.0001 (Z_4)$	-0.020	0.16	K-54
$\ln Y_9 = 5.7514 + 0.0119 (Z_5)$	0.007	0.02	K-55
$\ln Y_9 = 5.6994 + 0.3333 (Z_7)$	0.052	1.11	K-56
$\ln Y_9 = 5.7304 - 0.0144 (Z_1) + 0.0572 (Z_2) + 0.3004 (Z_3)$	0.103	1.45	K-57

TABLE K-2--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
$\ln Y_9 = 5.7961 - 0.0282\ (Z_1) + 0.1355\ (Z_2) + 0.00002\ (Z_4)$	0.079	0.85	K-58
$\ln Y_9 = 5.7663 - 0.0295\ (Z_1) + 0.1535\ (Z_2) + 0.0453\ (Z_5)$	0.083	0.94	K-59
$\ln Y_9 = 5.7052 - 0.00002\ (Z_4) - 0.0019\ (Z_5) + 0.3269\ (Z_7)$	0.052	0.37	K-60

[a] See Table K-1 for a listing of the dependent and independent variables.

[b] Levels of significance: * 95 percent level
** 99 percent level

TABLE K-3

MULTIPLE REGRESSION EQUATIONS
ln BOD CONCENTRATION[a] VS. RISING LIMB PRECIPITATION VARIABLES

Test Area No.	Regression Equation[b]	Correlation (R)	F-Value[c]	Equation Number
1	$\ln Y_4 = 2.584 + 0.080 (Z_1) - 1.395 (Z_2) + 1.35 (Z_3)$	0.651	1.96	K-61
2	$\ln Y_4 = 3.148 - 0.185 (Z_1) + 0.154 (Z_2) - 5.71 (Z_3)$	0.788	5.46*	K-62
3	$\ln Y_4 = 2.139 - 0.018 (Z_1) - 0.402 (Z_2) - 0.17 (Z_3)$	0.356	1.06	K-63
4	$\ln Y_4 = 3.760 - 0.189 (Z_1) + 0.529 (Z_2) - 6.53 (Z_3)$	0.713	11.72**	K-64
5	$\ln Y_4 = 2.864 + 0.147 (Z_1) - 0.490 (Z_2) + 0.10 (Z_3)$	0.650	4.14*	K-65
6	$\ln Y_4 = 2.898 - 0.008 (Z_1) - 0.513 (Z_2) - 0.10 (Z_3)$	0.754	2.63	K-66
7	$\ln Y_4 = 1.793 + 0.166 (Z_1) - 2.177 (Z_2) + 2.25 (Z_3)$	0.684	2.35	K-67
8	$\ln Y_4 = 2.641 + 0.032 (Z_1) - 0.022 (Z_2) - 1.19 (Z_3)$	0.475	0.39	K-68
9	$\ln Y_4 = 2.699 - 0.086 (Z_1) - 0.357 (Z_2) + 1.02 (Z_3)$	0.930	12.82**	K-69
10	$\ln Y_4 = -6.922 + 2.096 (Z_1) - 8.644 (Z_2) + 31.58 (Z_3)$	0.833	3.78	K-70
11	$\ln Y_4 = -0.236 + 0.306 (Z_1) - 1.394 (Z_2) + 9.39 (Z_3)$	0.770	3.41	K-71
12	$\ln Y_4 = 2.117 + 0.037 (Z_1) - 0.878 (Z_2) + 1.40 (Z_3)$	0.893	21.08**	K-72
13	$\ln Y_4 = 3.831 - 0.291 (Z_1) + 0.258 (Z_2) - 2.88 (Z_3)$	0.848	4.26	K-73
14	$\ln Y_4 = 2.072 + 0.141 (Z_1) - 0.130 (Z_2) - 0.45 (Z_3)$	0.566	2.20	K-74
15	$\ln Y_4 = 3.686 - 0.098 (Z_1) - 0.627 (Z_2) - 2.09 (Z_3)$	0.678	4.81*	K-75

[a] BOD in mg/l.

[b] See Table K-1 for a listing of the dependent and independent variables.

[c] Levels of significance: * 95 percent level
** 99 percent level

TABLE K-4

SELECTION OF BEST UNIVARIATE LAND USE REGRESSION EQUATIONS FOR ALL TEST AREAS

Regression Equation[a]	Correlation (R)	F-Value[b]	Equation Number
Total Coliform (Thousands/100 ml)			
$M_1 = 430 - 363 (X_1)$	-0.856	35.76**	K-76
$M_1 = -23 + 5802 (X_{16})$	0.627	8.45*	K-77
$M_1 = -16 + 10.2 (X_{17})$	0.691	11.90**	K-78
Fecal Coliform (Thousands/100 ml)			
$M_2 = 0.75 + 0.158 (X_{25})$	0.514	4.66	K-79
Fecal Streptococcus (Thousands/100 ml)			
$M_3 = 7.2 + 112 (X_{16})$	0.288	1.18	K-80
BOD (mg/l)			
$M_4 = 10.0 + 1.41 (X_{19})$	0.479	3.88	K-81
COD (mg/l)			
$M_5 = 55 + 2.08 (X_{17})$	0.533	5.15*	K-82
$M_5 = 63 + 17.2 (X_{19})$	0.550	5.63*	K-83

TABLE K-4--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Organic Kjeldahl Nitrogen (mg/l)			
$M_7 = 0.60 + 7.76 (X_{13})$	0.553	5.73*	K-84
$M_7 = 1.18 - 0.016 (X_{22})$	-0.548	5.59*	K-85
Soluble Orthophosphate (mg/l)			
$M_8 = 0.64 + 15.8 (X_{13})$	0.508	4.51	K-86
$M_8 = 1.77 - 0.03 (X_{22})$	-0.455	3.40	K-87
$M_8 = 0.90 + 0.03 (X_{25})$	0.660	10.03**	K-88
$M_8 = 0.62 + 0.08 (X_{29})$	0.788	21.26**	K-89
Total Solids (mg/l)			
$M_9 = 165 + 11,750 (X_{13})$	0.555	5.79*	K-90
$M_9 = 915 - 18.0 (X_{22})$	-0.401	2.49	K-91
$M_9 = 363 + 24.4 (X_{25})$	0.729	14.71**	K-92
$M_9 = 212 + 50.2 (X_{29})$	0.733	15.13**	K-93
Suspended Solids (mg/l)			
$M_{12} = -3 + 11,430 (X_{13})$	0.554	5.75*	K-94
$M_{12} = 187 + 24.0 (X_{25})$	0.736	15.39**	K-95
$M_{12} = 54 + 47.3 (X_{29})$	0.708	13.06**	K-96

[a] See Table K-1 for a listing of the dependent and independent variables.

[b] Levels of significance: * 95 percent level
** 99 percent level

TABLE K-5

REGRESSION EQUATIONS FOR COMMON PREDICTOR VARIABLES[a]

Regression Equation[b]	Correlation (R)	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)			
$M_1 = 565 - 420 (X_1) - 49.3 (X_{20}) - 6.70 (D_9)$	0.885	9.67**	K-97
Fecal Coliform (Thousands/100 ml)			
$M_2 = -11.7 + 6.92 (X_1) + 6.25 (X_{20}) - 0.396 (D_9)$	0.900	11.33**	K-98
Fecal Streptococcus (Thousands/100 ml)			
$M_3 = 9.30 + 6.23 (X_1) + 4.28 (X_{20}) - 5.58 (D_9)$	0.585	1.39	K-99
BOD (mg/l)			
$M_4 = 8.2 + 0.00065 (D_2)$	0.590	5.35**	K-100
$M_4 = 8.0 + 0.00138 (D_3)$	0.520	3.70	K-101
$M_4 = 10.6 + 582 (X_{14})$	0.306	1.03	K-102
$M_4 = 10.0 + 1.35 (X_{19})$	0.421	2.15	K-103
$M_4 = 7.3 - 0.724 (X_1) + 0.679 (X_{20}) + 0.00073 (D_2)$	0.627	1.73	K-104

TABLE K-5--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
COD (mg/l)			
$M_5 = 56 + 0.0056 (D_2)$	0.506	3.44	K-105
$M_5 = 50 + 0.0136 (D_3)$	0.511	3.54	K-106
$M_5 = 70 + 3.03 (X_{21})$	0.526	3.83	K-107
$M_5 = 67 + 14.6 (X_{19})$	0.455	2.61	K-108
$M_5 = 71 - 45.4 (X_1) + 2.61 (X_{21}) + 0.00619 (D_2)$	0.839	6.32*	K-109
TOC (mg/l)			
$M_6 = 23.9 + 0.00135 (D_2)$	0.428	2.24	K-110
$M_6 = 21.3 + 0.00363 (D_3)$	0.475	2.92	K-111
$M_6 = 36.6 - 9.29 (D_9)$	-0.413	2.06	K-112
$M_6 = 26.5 + 3.56 (X_{19})$	0.386	1.75	K-113
$M_6 = 53.5 - 19.5 (X_1) - 0.757 (X_{22}) + 0.00157 (D_2)$	0.648	1.93	K-114
Organic Kjeldahl Nitrogen (mg/l)			
$M_7 = 0.30 + 0.0049 (D_4)$	0.668	8.05*	K-115
$M_7 = 0.16 + 0.266 (D_6)$	0.882	34.87**	K-116
$M_7 = 0.52 + 0.429 (X_1)$	0.406	1.97	K-117
$M_7 = 0.65 + 79.8 (X_{14})$	0.413	2.06	K-118
$M_7 = 1.19 - 0.045 (X_{18})$	-0.534	3.99	K-119
$M_7 = 0.96 - 0.379 (X_{20})$	-0.562	4.60	K-120
$M_7 = 0.23 - 0.00 (X_{17}) - 0.029 (X_{20}) + 0.256 (D_6)$	0.887	9.81**	K-121

TABLE K-5--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Soluble Orthophosphate (mg/l)			
$M_8 = 0.53 + 0.0043\ (D_4)$	0.579	5.05*	K-122
$M_8 = 0.82 + 0.402\ (D_9)$	0.501	3.36	K-123
$M_8 = 1.28 - 1.24\ (X_{15})$	-0.265	0.75	K-124
$M_8 = 0.59 - 0.00\ (X_{17}) - 0.027\ (X_{20}) + 0.0042\ (D_4)$	0.584	1.38	K-125
Total Solids (mg/l)			
$M_9 = 318 + 0.303\ (D_1)$	0.626	6.45*	K-126
$M_9 = 199 + 2.05\ (D_4)$	0.671	8.20*	K-127
$M_9 = 332 + 62.8\ (X_{19})$	0.464	2.74	K-128
$M_9 = 130 + 8.99\ (X_{20}) + 2.59\ (X_{22}) + 2.06\ (D_4)$	0.690	2.42	K-129
Suspended Solids (mg/l)			
$M_{12} = 24 + 4.69\ (X_{20}) + 4.38\ (X_{22}) + 1.08\ (D_4)$	0.629	1.74	K-130

[a] Test Areas 1, 12, and 14 omitted.

[b] See Table K-1 for a listing of the dependent and independent variables.

[c] Levels of significance: * 95 percent level
** 99 percent level

TABLE K-6

REGRESSION EQUATIONS FOR RESIDENTIAL AREAS[a]

Regression Equation[b]	Correlation (R)	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)			
$M_1 = 521 - 427 (X_1)$	-0.883	17.75**	K-131
$M_1 = -62 + 14 (X_{17})$	0.828	10.70*	K-132
$M_1 = -192 + 320 (X_{20}$	0.798	8.79*	K-133
$M_1 = -106 + 15 (X_{22})$	0.514	1.80	K-134
$M_1 = 303 - 290 (X_1) + 6.21 (X_{17})$	0.918	10.67*	K-135
$M_1 = 268 - 286 (X_1) + 3.99 (X_{17}) + 61.8 (X_{20})$	0.920	5.49	K-136
$\ln M_1 = 3.7475 - 0.738 (X_1) + 0.054 (X_{17}) + 0.638 (X_{20})$	0.778	1.54	K-137
$M_1 = 269 - 309 (X_1) - 137 (X_{20}) + 0.580 (D_9)$	0.915	5.16	K-138
Fecal Coliform (Thousands/100 ml)			
$M_2 = -0.175 + 1.276 (X_1)$	0.300	0.49	K-139
$M_2 = 1.333 - 0.027 (X_{17})$	-0.184	0.18	K-140
$M_2 = 1.866 - 0.877 (X_{20})$	-0.248	0.33	K-141
$M_2 = 2.413 - 0.081 (X_{22})$	-0.328	0.60	K-142
$\ln M_2 = -1.6916 + 1.626 (X_1) + 0.115 (X_{17}) - 2.097 (X_{20})$	0.360	0.15	K-143
$M_2 = 0.274 + 1.07 (X_1) - 0.245 (X_{20})$	0.304	0.20	K-144
$M_2 = 0.884 + 0.806 (X_1) - 0.396 (X_{20}) + 0.543 (D_9)$	0.452	0.26	K-145

TABLE K-6--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Fecal Streptococcus (Thousands/100 ml)			
$M_3 = 8.492 - 0.903\ (X_1)$	-0.050	0.01	K-146
$M_3 = 8.837 - 0.065\ (X_{12})$	-0.106	0.06	K-147
$M_3 = 5.739 + 1.790\ (X_{20})$	0.120	0.07	K-148
$M_3 = 6.08 + 0.088\ (X_{22})$	0.084	0.04	K-149
$\ln M_3 = 2.4741 - 1.216\ (X_1) - 0.115\ (X_{17}) + 2.076\ (X_{20})$	0.545	0.42	K-150
$M_3 = 3.80 + 1.30\ (X_1) + 2.56\ (X_{20})$	0.130	0.03	K-151
$M_3 = 2.34 + 0.645\ (X_1) + 2.18\ (X_{20}) + 1.36\ (D_9)$	0.237	0.06	K-152
BOD (mg/l)			
$M_4 = 9.8 + 3.0\ (X_1)$	0.215	0.24	K-153
$M_4 = 13.9 - 0.1\ (X_{17})$	-0.198	0.20	K-154
$M_4 = 17.0 - 4.2\ (X_{20})$	-0.359	0.74	K-155
$M_4 = 21.7 - 0.5\ (X_{22})$	-0.605	2.89	K-156
$M_4 = 9.1 - 2.79\ (X_1) + 0.182\ (X_{20}) + 0.00091\ (D_2)$	0.621	0.63	K-157
$\ln M_4 = 4.7221 - 0.879\ (X_1) + 0.259\ (X_{20}) - 0.195\ (X_{21}) - 0.091\ (X_{22})$	0.674	0.42	K-158
$M_4 = 21.4 + 3.66\ (X_{20}) - 0.700\ (X_{22})$	0.635	1.35	K-159
COD (mg/l)			
$M_5 = 126 - 46\ (X_1)$	-0.336	0.63	K-160
$M_5 = 62 + 1.6\ (X_{17})$	0.334	0.63	K-161
$M_5 = 87 + 0.2\ (X_{20})$	0.002	0.00	K-162

TABLE K-6--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
$M_5 = 126 - 2.1\ (X_{22})$	-0.260	0.36	K-163
$M_5 = 69 - 74.71\ (X_1) + 3.68\ (X_{21}) + 0.0105\ (D_2)$	0.971	16.55*	K-164
$M_5 = 295 - 111\ (X_1) + 0.963\ (X_{21}) - 6.40\ (X_{22})$	0.759	1.36	K-165
$\ln M_5 = 4.3850 - 1.956\ (X_1) - 0.002\ (X_{21}) - 0.118\ (X_{22}) - 0.023\ (X_{29})$	0.844	1.24	K-166
Organic Kjeldahl Nitrogen (mg/l)			
$M_7 = 0.44 + 0.54\ (X_1)$	0.348	0.69	K-167
$M_7 = 1.48 - 0.04\ (X_{17})$	-0.670	4.07	K-168
$M_7 = 2.01 - 1.00\ (X_{20})$	-0.779	7.73*	K-169
$M_7 = 1.69 - 0.04\ (X_{22})$	-0.476	1.47	K-170
$M_7 = 2.13 + 0.0152\ (X_{17}) - 1.34\ (X_{20})$	0.787	3.26	K-171
$\ln M_7 = 1.3895 + 0.046\ (X_{17}) - 2.145\ (X_{20})$	0.797	3.47	K-172
$M_7 = 0.02 - 0.0072\ (X_{17}) + 0.200\ (X_{20}) + 0.286\ (D_6)$	0.889	3.78	K-173
Soluble Orthophosphate (mg/l)			
$M_8 = 0.97 + 0.14\ (X_1)$	0.094	0.04	K-174
$M_8 = 1.32 - 0.01\ (X_{17})$	-0.276	0.41	K-175
$M_8 = 1.60 - 0.45\ (X_{20})$	-0.364	0.76	K-176
$M_8 = 1.73 - 0.03\ (X_{22})$	-0.391	0.90	K-177
$M_8 = -1.01 - 0.039\ (X_{17}) + 1.56\ (X_{20}) + 0.0095\ (D_4)$	0.803	1.82	K-178
$M_8 = 0.66 - 0.0011\ (X_{21}) + 0.0645\ (X_{29})$	0.817	4.01	K-179
$\ln M_8 = -0.3482 + 0.0075\ (X_{21}) + 0.051\ (X_{29})$	0.804	3.64	K-180

TABLE K-6--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Total Solids (mg/l)			
$M_9 = 384 + 37 (X_1)$	0.073	0.03	K-181
$M_9 = 224 - 1.6 (X_{17})$	-0.107	0.06	K-182
$M_9 = 577 - 144 (X_{20})$	-0.344	0.67	K-183
$M_9 = 498 - 4.4 (X_{22})$	-0.148	0.11	K-184
$M_9 = 481 - 326 (X_{20}) + 5.50 (X_{21}) + 14.2 (X_{22})$	0.435	0.23	K-185
$\ln M_9 = 6.0338 - 0.904 (X_{20}) + 0.022 (X_{21}) + 0.045 (X_{22})$	0.507	0.34	K-186
$M_9 = -139 - 15.4 (X_{20}) + 16.0 (X_{22}) + 2.57 (D_4)$	0.765	1.41	K-187
Dissolved Solids (mg/l)			
$M_{10} = 150 + 71.8 (X_1) + 14.9 (X_{20}) - 5.11 (X_{21})$	0.334	0.13	K-188
$\ln M_{10} = 5.0566 + 0.244 (X_1) - 0.028 (X_{20}) - 0.013 (X_{21})$	0.231	0.06	K-189
Suspended Solids (mg/l)			
$M_{12} = 791 - 312 (X_1) - 288 (X_{20}) + 1.32 (X_{21})$	0.828	2.17	K-190
$\ln M_{12} = 8.0193 - 1.589 (X_1) - 1.381 (X_{20}) + 0.012 (X_{21})$	0.764	1.40	K-191
$M_{12} = 267 - 81 (X_{20}) + 0.88 (X_{22}) + 0.23 (D_4)$	0.385	0.17	K-192

[a] Test Areas No. 3, 5, 7, 8, 9, 13, and 15.

[b] See Table K-1 for a listing of the dependent and independent variables.

[c] Levels of significance: * 95 percent level
** 99 percent level

TABLE K-7

REGRESSION EQUATIONS FOR COMMERCIAL AND INDUSTRIAL AREAS[a]

Regression Equation[b]	Correlation (R)	F-Value[c]	Equation Number
Total Coliform (Thousands/100 ml)			
$M_1 = 372 - 329 (X_1)$	-0.930	25.66**	K-193
$M_1 = 126 + 1128 (X_{14})$	0.015	0.00	K-194
$M_1 = 69 + 34 (X_{20})$	0.308	0.42	K-195
$M_1 = 250 - 10 (X_{24})$	-0.711	4.08	K-196
$M_1 = 154 - 3 (X_{29})$	-0.206	0.18	K-197
$M_1 = 119 - 384 (X_1) - 19.5 (X_{19}) - 13.4 (D_9)$	0.951	9.46	K-198
$M_1 = 370 - 304 (X_1) - 1.47 (X_{24})$	0.933	10.06*	K-199
$\ln M_1 = 5.9923 - 1.240 (X_1) - 0.050 (X_{24})$	0.852	3.96	K-200
Fecal Coliform (Thousands/100 ml)			
$M_2 = 6.63 - 3.91 (X_1)$	-0.200	0.17	K-201
$M_2 = 13.13 - 2511 (X_{14})$	-0.584	2.07	K-202
$M_2 = -5.64 + 5.25 (X_{20})$	0.852	10.58*	K-203
$M_2 = 7.86 - 0.35 (X_{24})$	-0.438	0.95	K-204
$M_2 = 5.93 - 0.25 (X_{29})$	-0.332	0.49	K-205
$M_2 = -8.61 + 7.52 (X_1) + 5.65 (X_{20}) - 1.66 (D_9)$	0.897	4.10	K-206
$M_2 = 8.92 - 1.12 (X_1) - 0.574 (X_{21})$	0.497	0.49	K-207
$\ln M_2 = 1.2828 + 0.478 (X_1) - 0.183 (X_{21})$	0.718	1.60	K-208

TABLE K-7--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Fecal Streptococcus (Thousands/100 ml)			
$M_3 = 13.37 - 0.55 (X_1)$	-0.017	0.00	K-209
$M_3 = 37.29 - 6516 (X_{14})$	-0.912	19.65*	K-210
$M_3 = 7.24 + 3.20 (X_{20})$	0.312	0.43	K-211
$M_3 = 15.16 - 0.19 (X_{24})$	-0.141	0.08	K-212
$M_3 = 12.06 + 0.10 (X_{29})$	0.083	0.03	K-213
$M_3 = 36.40 - 8.78 (X_1) - 1290 (X_{14}) - 8.94 (D_9)$	0.660	0.77	K-214
$M_3 = 8.75 - 6.17 (X_1) - 0.522 (X_{21})$	0.552	0.66	K-215
$\ln M_3 = 2.2404 - 1.396 (X_1) + 0.108 (X_{21})$	0.503	0.51	K-216
BOD (mg/l)			
$M_4 = 14.3 - 3.1 (X_1)$	-0.489	1.26	K-217
$M_4 = 10.5 + 393 (X_{14})$	0.280	0.34	K-218
$M_4 = 11.3 + 0.38 (X_{20})$	0.191	0.15	K-219
$M_4 = 13.8 - 0.15 (X_{24})$	-0.578	2.01	K-220
$M_4 = 11.5 + 0.05 (X_{29})$	0.223	0.21	K-221
$M_4 = 8.3 - 0.709 (X_1) + 1.10 (X_{19}) + 0.00028 (D_2)$	0.830	2.22	K-222
$M_4 = 13.2 - 0.130 (X_{24}) + 0.202 (X_{25})$	0.599	0.84	K-223
$\ln M_4 = 2.5773 - 0.013 (X_{24}) + 0.0020 (X_{25})$	0.626	0.97*	K-224
COD (mg/l)			
$M_5 = 117 - 29 (X_1)$	-0.400	0.76	K-225
$M_5 = 94 + 247 (X_{14})$	0.015	0.00	K-226

TABLE K-7--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
$M_5 = 96 - 0.91 (X_{20})$	-0.040	0.01	K-227
$M_5 = 116 - 1.80 (X_{24})$	-0.598	2.23	K-228
$M_5 = 83 + 1.39 (X_{29})$	0.501	1.34	K-229
$M_5 = 152 - 52.2 (X_1) + 1.72 (X_{21}) - 21.7 (D_9)$	0.862	2.89	K-230
$M_5 = 116 - 1.78 (X_{24}) + 0.0108 (X_{25})$	0.598	0.84	K-231
$\ln M_5 = 4.7686 - 0.024 (X_{24}) + 0.0011 (X_{25})$	0.609	0.61	K-232
TOC (mg/l)			
$M_6 = 3.8 + 4.76 (X_1) + 2.10 (X_{19}) + 0.0055 (D_3)$	0.970	15.74*	K-233
Organic Kjeldahl Nitrogen (mg/l)			
$M_7 = 0.57 + 0.41 (X_1)$	0.805	7.38	K-234
$M_7 = 0.65 + 56 (X_{14})$	0.505	1.37	K-235
$M_7 = 1.08 - 0.12 (X_{20})$	-0.772	5.89	K-236
$M_7 = 0.73 + 0.01 (X_{24})$	0.542	1.66	K-237
$M_7 = 0.76 + 0.01 (X_{29})$	0.579	2.02	K-238
$M_7 = 0.79 + 0.277 (X_1) - 0.0742 (X_{20})$	0.889	5.65	K-239
$\ln M_7 = -0.2588 + 0.340 (X_1) - 0.089 (X_{20})$	0.909	7.17	K-240
$M_7 = 0.31 - 0.0810 (X_1) - 0.0507 (X_{20}) + 0.265 (D_6)$	0.958	11.24*	K-241
Soluble Orthophosphate (mg/l)			
$M_8 = 0.74 + 0.83 (X_1)$	0.279	0.34	K-242
$M_8 = 0.17 + 315 (X_{14})$	0.483	1.22	K-243

TABLE K-7--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
$M_8 = 2.14 - 0.44 (X_{20})$	-0.473	1.15	K-244
$M_8 = 1.75 - 0.04 (X_{24})$	-0.285	0.35	K-245
$M_8 = 0.57 + 0.09 (X_{29})$	0.782	6.31	K-246
$M_8 = 2.74 - 1.20 (X_1) + 0.118 (X_{29}) - 0.0131 (D_4)$	0.853	2.67	K-247
$M_8 = 1.35 + 0.0252 (X_{25}) + 0.0622 (X_{29})$	0.882	5.26	K-248
$\ln M_8 = -0.3833 + 0.0151 (X_{25}) + 0.0272 (X_{29})$	0.834	3.43	K-249
Total Solids (mg/l)			
$M_9 = 306 + 600 (X_1)$	0.288	0.36	K-250
$M_9 = -72 + 206,154 (X_{14})$	0.451	1.02	K-251
$M_9 = 1348 - 335 (X_{20})$	-0.512	1.42	K-252
$M_9 = 1024 - 24 (X_{24})$	-0.277	0.33	K-253
$M_9 = 162 + 67 (X_{29})$	0.839	9.51*	K-254
$M_9 = 1426 - 715 (X_1) + 83.0 (X_{29}) - 7.43 (D_4)$	0.885	3.62	K-255
$M_9 = 49 + 45.4 (X_{20}) + 70.1 (X_{29})$	0.841	3.61	K-256
$\ln M_9 = 5.6104 + 0.0063 (X_{20}) + 0.0697 (X_{29})$	0.823	3.14	K-257
Dissolved Solids (mg/l)			
$M_{10} = 150 + 9.20 (X_{20}) + 1.42 (X_{29})$	0.172	0.05	K-258
$\ln M_{10} = 4.8192 + 0.090 (X_{20}) + 0.0134 (X_{29})$	0.295	0.14	K-259

TABLE K-7--Continued

Regression Equation	Correlation (R)	F-Value	Equation Number
Suspended Solids (mg/l)			
$M_{12} = -3 + 65.9\ (X_{29})$	0.848	10.25*	K-260
$M_{12} = 1392 - 746\ (X_1) + 83.1\ (X_{29}) - 8.37\ (D_4)$	0.898	4.18	K-261
$M_{12} = -93 + 36.1\ (X_{20}) + 68.7\ (X_{29})$	0.849	3.88	K-262
$\ln M_{12} = 5.1296 + 0.032\ (X_{20}) + 0.0840\ (X_{29})$	0.853	4.02	K-263

[a] Test Areas No. 1, 2, 4, 6, 10, and 11.

[b] See Table K-1 for a listing of the dependent and independent variables.

[c] Levels of Significance: * 95 percent level
** 99 percent level

APPENDIX L

MONTHLY PRECIPITATION DATA FOR SIX RAIN GAGES IN THE URBAN TULSA AREA

The following table gives the monthly precipitation data for six rain gages located in Tulsa for the years 1964 through 1969. Gages No. 1-5 are maintained by the City of Tulsa Engineering Department. Gage No. 6 is the official Environmental Science Services Administration gage located at the Tulsa International Airport. The data from these six gages were used for the calculations of expected storm water runoff volumes.

Locations of the rain gages are illustrated in Figure 2 in Section 3.

TABLE L-1

MONTHLY PRECIPITATION FOR SIX RAIN GAGES
TULSA, OKLAHOMA[a]

1964

Month	Gage Number							Average[c]
	1	2	3	4	5	6	6*[b]	
Jan.	0.40	0.45	0.40	0.50	0.50	0.63	0.54	0.46
Feb.	1.05	1.00	1.20	1.20	1.85	2.17	2.13	1.40
Mar.	2.85	2.55	2.60	2.35	2.45	3.96	3.82	2.77
Apr.	4.70	5.40	4.05	5.20	4.30	5.87	5.72	4.89
May	3.95	4.25	3.90	3.85	3.75	4.77	4.64	4.06
June	3.60	3.90	4.35	6.55	3.60	5.79	5.50	4.58
July	0.25	0.30	1.45	0.30	1.05	1.80	1.75	0.85
Aug.	3.90	3.55	4.15	3.90	4.00	6.14	6.02	4.25
Sept.	1.35	1.10	1.85	1.15	1.75	3.33	3.17	1.73
Oct.	1.05	1.00	1.00	0.80	1.05	1.24	1.24	1.03
Nov.	4.65	5.15	4.65	5.05	4.70	6.90	6.73	5.15
Dec.	1.00	1.05	1.05	1.15	1.05	1.67	1.56	1.16
Total	28.75	29.70	30.65	32.00	30.05	44.27	42.82	32.33

1965

Month	Gage Number							Average
	1	2	3	4	5	6	6*	
Jan.	1.15	0.75	0.70	1.15	0.85	1.56	1.51	1.02
Feb.	0.75	0.85	0.90	0.85	0.85	1.45	1.31	1.09
Mar.	0.55	0.60	0.55	0.50	0.60	0.73	0.62	1.07
Apr.	1.80	1.75	1.35	2.00	1.85	3.00	2.85	2.77
May	4.85	3.85	4.70	3.95	3.90	3.91	3.76	4.16
June	2.15	2.30	2.10	1.30	1.75	3.76	3.68	2.21
July	4.55	2.30	3.95	4.55	2.95	3.39	3.28	4.43
Aug.	2.55	3.15	2.10	1.60	4.40	3.72	3.64	2.91
Sept.	4.30	1.70	3.15	4.00	2.60	4.59	4.54	3.38
Oct.	0.25	0.25	0.45	0.00	0.15	0.26	0.24	0.27
Nov.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec.	2.80	2.75	3.05	2.95	2.80	4.29	4.24	3.10
Total	25.70	20.25	23.00	22.85	22.70	30.66	29.67	26.41

TABLE L-1--Continued

1966

Month	Gage Number							Average
	1	2	3	4	5	6	6*	
Jan.	0.50	0.45	1.50	0.35	0.55	0.69	0.53	0.48
Feb.	1.50	1.95	2.05	1.50	2.00	2.35	2.19	1.87
Mar.	0.50	0.95	0.70	0.75	0.80	0.86	0.86	0.74
Apr.	3.95	3.80	3.55	2.70	2.65	4.84	4.70	3.56
May	0.40	0.95	0.50	1.85	0.90	1.86	1.83	1.07
June	2.10	2.65	1.85	1.90	3.30	2.56	2.56	2.39
July	2.45	2.15	4.00	2.35	1.85	2.00	1.98	2.46
Aug.	3.40	2.70	3.20	2.25	4.05	4.59	4.45	3.34
Sept.	3.45	3.60	3.15	1.55	4.60	2.68	2.54	3.15
Oct.	0.90	0.70	1.35	0.35	0.90	1.39	1.26	0.91
Nov.	0.25	0.30	0.35	0.30	0.80	0.51	0.44	0.41
Dec.	2.40	2.00	2.10	1.90	2.05	2.53	2.46	2.15
Total	21.80	22.20	23.30	17.75	24.45	26.86	25.80	22.53

1967

Month	Gage Number							Average
	1	2	3	4	5	6	6*	
Jan.	1.45	1.40	1.20	1.20	1.75	1.51	1.51	1.42
Feb.	0.50	0.30	0.40	0.65	0.30	0.65	0.45	0.44
Mar.	1.30	1.15	1.05	1.50	1.20	1.42	1.09	1.25
Apr.	5.30	3.95	4.00	5.15	5.00	5.09	4.41	4.69
May	5.50	5.30	6.25	5.10	5.65	5.34	5.34	5.52
June	4.90	4.70	4.20	1.90	4.10	4.60	4.53	4.07
July	4.90	4.05	5.35	2.65	4.90	6.88	6.76	4.77
Aug.	0.80	1.10	0.80	0.45	0.85	0.57	0.34	0.73
Sept.	5.20	5.80	6.70	5.40	3.95	4.89	3.80	5.14
Oct.	3.85	3.20	3.15	3.35	3.35	3.75	3.74	3.39
Nov.	0.75	0.65	0.80	0.80	0.85	1.09	1.06	0.79
Dec.	0.60	0.25	0.25	0.20	0.40	1.12	0.76	0.37
Total	35.05	31.85	34.15	28.35	32.30	36.91	33.79	32.58

TABLE L-1--Continued

1968

Month	Gage Number							Average
	1	2	3	4	5	6	6*	
Jan.	3.25	3.05	2.95	3.10	3.75	3.26	2.89	3.18
Feb.	0.70	0.80	0.65	0.95	1.00	1.08	0.97	0.85
Mar.	3.40	3.25	2.60	3.05	3.95	3.49	3.30	3.26
Apr.	4.15	3.25	3.75	3.55	5.20	4.40	4.33	4.04
May	2.90	2.90	2.40	2.20	2.70	3.56	3.46	2.76
June	4.50	6.00	5.55	3.90	6.95	4.08	4.08	5.16
July	0.95	0.90	1.55	2.15	1.45	1.37	1.32	1.39
Aug.	2.45	2.50	3.10	2.55	3.40	1.90	1.80	2.63
Sept.	2.05	2.15	2.20	1.45	1.35	2.80	2.75	1.99
Oct.	2.30	2.05	2.00	2.60	1.90	2.64	2.64	2.25
Nov.	5.90	5.10	4.50	5.80	4.25	5.19	5.00	5.09
Dec.	1.80	1.40	1.60	1.80	1.90	2.01	1.91	1.74
Total	34.35	33.35	32.85	33.10	37.80	35.78	34.54	34.34

1969

Month	Gage Number							Average
	1	2	3	4	5	6	6*	
Jan.	1.50	1.30	1.60	1.35	1.80	1.63	1.42	1.50
Feb.	1.65	1.60	1.65	1.45	1.40	1.34	1.28	1.51
Mar.	2.90	2.80	2.75	2.95	3.25	3.25	3.03	2.95
Apr.	1.75	1.90	2.15	1.60	2.30	1.56	1.35	1.84
May	2.00	1.50	1.25	1.95	1.15	1.98	1.81	1.61
June	5.95	4.90	6.85	6.30	4.25	6.40	6.28	5.76
July	0.75	0.55	0.85	0.80	0.85	1.03	0.98	0.80
Aug.	2.80	2.20	2.85	1.95	2.65	3.24	3.24	2.62
Sept.	0.95	1.20	1.00	1.05	1.00	1.67	1.51	1.12
Oct.	5.60	4.65	5.30	5.65	5.15	5.86	5.83	5.36
Nov.	0.35	0.30	0.45	0.20	0.65	0.32	0.00	0.33
Dec.	1.25	1.10	1.25	1.10	1.15	1.62	1.25	1.18
Total	27.45	24.00	27.95	26.35	25.60	29.90	27.98	26.56

[a] Rainfall amounts in inches.

[b] Adjusted values for Gage No. 6 obtained by deleting events less than 0.2 inches.

[c] Arithmetic average of Gages 1-5 and 6*.

TABLE L-2

AVERAGE FREQUENCY OF RAINFALL EVENTS, TULSA, OKLAHOMA[a, b, c]

	Rainfall Interval (Inches)												
Month	0.01 to 0.10[d]	0.11 to 0.20	0.21 to 0.40	0.41 to 0.60	0.61 to 0.80	0.81 to 1.00	1.01 to 1.20	1.21 to 1.40	1.41 to 1.60	1.61 to 1.80	1.81 to 2.00	>2.00	Total
Jan.	4.2	0.6	0.2	0.6	0.2	0.6	0.0	0.0	0.2	0.2	0.0	0.0	6.8
Feb.	3.8	1.2	1.2	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	6.8
Mar.	3.8	0.8	0.6	0.4	0.4	0.4	0.2	0.4	0.0	0.0	0.0	0.0	7.0
Apr.	4.6	1.6	2.6	0.8	0.8	0.8	0.4	0.0	0.0	0.2	0.0	0.2	12.0
May	4.4	1.0	2.2	1.0	0.6	0.6	0.2	0.0	0.4	0.0	0.0	0.2	10.6
June	3.2	0.8	0.8	1.2	0.8	0.2	0.4	0.6	0.0	0.4	0.2	0.0	8.6
July	2.2	1.4	1.0	0.6	0.2	0.2	0.6	0.2	0.0	0.0	0.0	0.4	6.8
Aug.	3.6	1.2	1.8	0.0	0.2	0.6	0.2	0.4	0.2	0.0	0.2	0.2	8.6
Sept.	3.6	0.4	0.8	1.0	0.4	0.6	0.6	0.0	0.2	0.0	0.2	0.2	8.0
Oct.	1.0	0.6	0.6	0.4	0.6	0.4	0.0	0.4	0.0	0.0	0.0	0.0	4.0
Nov.	3.0	0.2	1.0	1.4	0.4	0.4	0.0	0.4	0.0	0.0	0.0	0.2	7.0
Dec.	3.6	0.4	1.4	0.4	0.2	0.0	0.2	0.2	0.6	0.2	0.0	0.2	6.8
Total	41.0	10.2	14.2	8.2	4.8	5.0	2.8	2.6	1.0	1.0	0.6	1.6	93.0

[a] Number of events per month falling within rainfall interval.

[b] Five-year record (1964-1968). Source: Local Climatological Data, Tulsa Internationa Airport, Tulsa, Oklahoma.

[c] The precipitation was considered to represent only one event if not more than two hours without precipitation elasped between individual hourly events.

[d] Trace amounts and amounts equal to or less than 0.01 were treated as no rainfall.

TABLE L-3

AVERAGE MONTHLY RAINFALL AMOUNT OCCURRING WITHIN SPECIFIC RAINFALL INTERVALS[a]

Month	Rainfall Interval (Inches) 0.01 to 0.10	0.11 to 0.20	0.21 to 0.40	0.41 to 0.60	0.61 to 0.80	0.81 to 1.00	1.01 to 1.20	1.21 to 1.40	1.41 to 1.60	1.61 to 1.80	1.81 to 2.00	>2.00	Total
Jan.	0.21	0.09	0.06	0.30	0.14	0.54	0.00	0.00	0.30	0.34	0.00	0.00	1.98
Feb.	0.19	0.18	0.36	0.20	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Mar.	0.19	0.12	0.18	0.20	0.28	0.36	0.22	0.52	0.00	0.00	0.00	0.00	2.07
Apr.	0.23	0.24	0.78	0.40	0.56	0.72	0.44	0.00	0.00	0.34	0.00	0.54	4.25
May	0.22	0.15	0.66	0.50	0.42	0.54	0.22	0.00	0.60	0.00	0.00	0.54	3.85
June	0.16	0.12	0.24	0.60	0.56	0.18	0.44	0.78	0.00	0.68	0.38	0.00	4.14
July	0.11	0.21	0.30	0.30	0.14	0.18	0.66	0.26	0.00	0.00	0.00	1.08	3.24
Aug.	0.18	0.18	0.54	0.00	0.14	0.54	0.22	0.52	0.30	0.00	0.38	0.54	3.54
Sept.	0.18	0.06	0.24	0.50	0.28	0.54	0.66	0.00	0.30	0.00	0.38	0.54	3.68
Oct.	0.05	0.09	0.18	0.20	0.42	0.36	0.22	0.52	0.00	0.00	0.00	0.00	2.04
Nov.	0.15	0.03	0.30	0.7-	0.28	0.36	0.66	0.52	0.00	0.00	0.00	0.54	3.54
Dec.	0.18	0.06	0.42	0.20	0.14	0.00	0.22	0.26	0.00	0.34	0.00	0.54	2.26
Total	2.05	1.53	4.26	4.10	3.36	4.50	3.96	3.38	1.50	1.70	1.14	4.32	35.80

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[a] The rainfall amount for each interval is based on the average number of events per interval (from Table L-2) times the average amount of the rainfall interval. For example, there are,on the average, 0.6 precipitation events between 0.41 and 0.60 inches during January. The average amount of the interval is 0.50 inches. Therefore, the average rainfall amount per interval is 0.6 x 0.50 in. = 0.30 in., which is the value listed above.

APPENDIX M

ANALYTICAL RESULTS

Table M-1 presents the analytical results obtained from samples collected during dry-weather flow. It should be noted that Test Areas 9, 14, and 15 did not have any dry-weather flows on the days indicated. The other twelve test areas exhibited small amounts of flow at the sample collection times. These samples may be considered representative of water seepage into the storm drain system.

Analytical results for samples taken during periods of storm water runoff are shown in Table M-2. Also included are data for the precipitation variables for each sample collected.

LEGEND FOR TABLES M-1 AND M-2

Abbreviation	Units	Item
T. COL.	number/ml	Total coliform
F. COL.	number/ml	Fecal coliform
F. STREP.	number/ml	Fecal streptococcus
BOD	mg/l	Biochemical oxygen demand (5-days, 20°C)
COD	mg/l	Chemical oxygen demand
TOC	mg/l	Total organic carbon
N	mg/l	Organic Kjeldahl nitrogen
PO4	mg/l	Soluble orthophosphate
TOTAL	mg/l	Total solids
DS	mg/l	Dissolved solids
VDS	mg/l	Volatile dissolved solids
SS	mg/l	Suspended solids
VSS	mg/l	Volatile suspended solids
PH	none	pH
CL	mg/l	Chloride
COND	micromhos/cm	Specific conductance
TIME SINCE START	hr.	The length of time from the beginning of rainfall to the start of the sample composite period

Abbreviation	Units	Item
ANT. AMOUNT	in.	The amount of rainfall accumulated from the start of rainfall to the start of the sample period
ANT. AVERAGE INTENSITY	in. /hr.	The average intensity preceding sample collection
TIME SINCE ANT. EVENT	hr.	The time elapsed since the last measurable precipitation event
AMOUNT OF ANT. EVENT	in.	The total precipitation of the antecedent event
DURATION OF ANT. EVENT	hr.	The duration of the antecedent event
AVERAGE INTENSITY ANT. EVENT	in. /hr.	The average intensity of the antecedent event
API	in.	Antecedent precipitation index

TABLE M-1

ANALYTICAL RESULTS OF BASELINE SAMPLES[a]

TEST AREA NO.	DATE	DAYS SINCE LAST PREC. EVENT	BACTERIOLOGICAL (number /ml)			ORGANIC (mg/l)			NUTRIENT (mg/l)		SOLIDS (mg/l)					OTHER		
			T. COL.	F. COL.	F. STREP.	BOD	COD	TOC	N	P04	TOTAL	DS	VDS	SS	VSS	PH	CL	COND
1	2-11	11	20	0	0	2	24	7	0.28	1.00	240	240	60	0	60	7.2	n. d.	n. d.
	3-12	4	0	0	0	5	28	11	0.35	1.00	360	360	128	0	128	8.5	38	328
	6-11	2	0	4	78	3	34	6	0.00	1.02	380	372	240	8	240	8.6	25	255
	7-30	35	50	2	0	10	90	n. d.	0.97	0.60	528	488	136	40	136	9.1	50	300
2	3-12	7	125	0	0	2	12	4	0.42	0.40	528	528	160	0	160	8.5	35	417
3	2-11	11	0	0	0	0	8	10	0.14	0.05	76	76	24	0	24	7.3	n. d.	n. d.
	3-12	4	0	0	0	3	44	8	0.28	0.00	328	300	300	0	300	8.0	29	348
	6-11	2	10	8	170	1	13	6	0.00	0.10	432	388	168	44	168	8.0	32	292
	7-30	35	0	1	0	3	31	n. d.	0.24	0.02	560	512	252	48	252	8.0	74	316
4	2-11	11	0	0	0	3	20	40	0.28	0.90	1068	1060	200	8	200	7.5	n. d.	n. d.
	3-12	7	35	0	0	4	20	9	0.35	0.20	856	852	200	4	200	8.0	37	682
	6-11	2	500	25	165	1	50	2	0.00	0.82	1480	1468	384	12	384	8.1	63	643
	7-30	35	200	0	150	3	15	n. d.	0.22	0.82	2128	2108	844	20	844	7.9	77	675
5	2-11	11	100	0	0	1	6	5	0.49	0.05	440	420	60	20	60	7.2	n. d.	n. d.
	3-12	7	170	0	0	2	8	7	0.20	0.10	228	228	120	0	120	8.3	9	154
6	2-11	11	500	0	5	2	26	10	0.00	0.72	520	520	100	0	0	7.3	n. d	n. d.
	3-12	7	680	0	0	6	24	17	0.49	0.30	500	500	148	0	0	8.0	50	306
	6-11	2	800	80	160	1	30	0	0.03	1.50	364	344	204	20	20	8.1	50	411
	7-30	35	350	0	0	6	30	n. d.	2.53	4.40	668	648	240	20	16	8.1	65	387
7	3-12	7	240	0	0	2	20	3	0.28	0.60	904	880	208	24	12	[illegible] 6	118	537
	6-11	2	830	70	420	2	3	0	0.01	0.55	868	820	292	48	44	7.9	112	511
	7-30	35	650	37	10	36	116	n. d.	0.85	0.90	968	924	320	44	22	7.5	110	512
8	6-11	2	250	13	140	5	52	16	0.00	1.06	636	632	208	4	4	7.6	33	238
	7-30	35	5,900	52	2,900	17	97	n. d.	0.53	0.62	568	544	268	24	24	7.6	36	282
10	3-12	7	0	0	0	0	20	10	0.28	0.30	268	260	132	8	0	8.0	32	216
	7-30	35	1,100	5	10	10	18	n. d.	0.39	0.60	1124	500	160	624	96	7.9	55	304
11	2-11	11	100	0	0	0	19	14	0.14	1.88	588	568	88	20	12	7.1	n. d.	n. d.
	3-12	7	270	0	0	0	52	14	0.91	0.60	680	480	12	200	72	8.0	43	420
	7-30	35	2,900	2	20	20	7	n. d.	0.86	2.11	436	424	240	12	12	7.9	15	218
12	2-11	11	400	0	0	0	16	15	0.28	0.18	320	320	40	0	0	7.0	n. d.	n. d.
	3-12	4	15	0	0	0	24	16	0.28	0.00	416	408	140	8	0	8.0	41	358
	6-11	2	190	10	2,000	2,000	40	4	0.00	0.32	124	108	20	16	16	7.4	11	140
	7-30	35	0	0	0	0	10	n. d.	0.49	0.68	276	276	214	0	0	7.9	10	121
13	2-11	11	100	0	0	1	8	6	0.00	0.10	212	212	40	0	0	7.3	n. d.	n. d.
	3-12	7	0	0	0	3	12	5	0.14	0.00	444	440	88	4	0	8.6	25	223
	6-11	2	4,000	130	800	1	10	1	0.08	0.87	292	260	76	32	32	7.5	24	226

[a] n. d. =no data

TABLE M-2

ANALYTICAL RESULTS OF STORM WATER RUNOFF SAMPLES

TEST AREA NO. 1

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L									
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
100568	915	*******	****	10	***	***	***	*****	*****	****	****	****	****	****	9.6	***	***	2.3	0.31	0.13	265.	1.05	9.00	0.12	0.85
100568	945	*******	****	13	***	***	***	*****	*****	****	****	****	****	****	10.5	***	***	2.8	0.44	0.16	265.	1.05	9.00	0.12	0.85
100568	1015	332	****	57	***	***	***	*****	*****	****	****	****	****	****	10.3	***	***	3.3	0.60	0.18	265.	1.05	9.00	0.12	0.85
100568	1045	54	****	*******	***	***	***	*****	*****	****	****	****	****	****	10.4	***	***	3.8	0.80	0.21	265.	1.05	9.00	0.12	0.85
100568	1115	100	****	*******	***	***	***	*****	*****	****	****	****	****	****	9.3	***	***	4.3	0.94	0.22	265.	1.05	9.00	0.12	0.85
100568	1130	*******	****	32	***	***	***	*****	*****	****	****	****	****	****	8.8	***	***	4.5	0.98	0.22	265.	1.05	9.00	0.12	0.85
100968	665	50	****	320	7	***	***	*****	*****	548	236	73	312	96	9.4	14	***	2.4	0.59	0.25	58.	1.00	4.50	0.22	1.30
100968	710	20	****	413	29	***	***	*****	*****	3164	172	72	2992	1100	10.4	8	***	2.7	0.60	0.22	58.	1.00	4.50	0.22	1.30
100968	725	13	****	475	9	***	***	*****	*****	2172	80	40	2092	292	8.9	8	***	2.9	0.60	0.21	58.	1.00	4.50	0.22	1.30
100968	740	50	****	211	9	***	***	*****	*****	1920	40	28	1880	304	8.6	71	***	3.2	0.60	0.19	58.	1.00	4.50	0.22	1.30
100968	755	55	****	655	9	***	***	*****	*****	1672	48	28	1624	224	8.5	71	***	3.4	0.60	0.18	58.	1.00	4.50	0.22	1.30
100968	810	21	****	431	10	***	***	*****	*****	1376	40	20	1336	276	8.6	71	***	3.7	0.60	0.16	58.	1.00	4.50	0.22	1.30
101668	1855	80	****	21	34	***	***	*****	*****	5048	140	60	4908	836	11.2	14	***	4.9	0.34	0.07	163.	0.70	2.50	0.28	1.10
101668	1910	35	****	11	17	***	***	*****	*****	2608	272	96	2332	456	11.8	38	***	5.2	0.35	0.07	163.	0.70	2.50	0.28	1.10
101668	1525	10	****	13	23	***	***	*****	*****	2792	460	220	2332	620	12.2	7	***	5.4	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	1940	25	****	7	19	***	***	*****	*****	2252	332	140	1820	500	12.0	14	***	5.7	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	1955	27	****	10	21	***	***	*****	*****	1300	160	92	1140	240	11.4	14	***	5.9	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	2010	45	****	15	23	***	***	*****	*****	1924	168	108	1756	300	10.7	17	***	6.2	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	2025	*******	****	*******	19	***	***	*****	*****	2084	180	72	1904	290	9.8	14	***	6.4	0.35	0.05	163.	0.70	2.50	0.28	1.10
22069	1350	0	0	2	20	132	64	2.24	1.90	992	32	12	960	184	9.3	14	180	6.8	0.53	0.08	110.	0.45	26.00	0.02	0.40
22069	1355	75	0	0	6	44	35	1.40	1.10	664	192	72	472	48	7.1	10	176	6.9	0.54	0.08	110.	0.45	26.00	0.02	0.40
22069	1630	275	0	10	5	36	87	1.40	1.10	640	160	88	480	60	7.3	9	165	9.5	0.60	0.06	110.	0.45	26.00	0.02	0.40
32369	945	100	0	0	3	62	27	2.24	1.90	1400	100	60	1300	260	7.8	4	96	12.8	1.41	0.11	742.	0.40	12.00	0.03	0.40
32369	1350	80	1	0	3	62	27	2.24	1.90	1400	100	60	1300	260	7.8	4	96	16.8	2.25	0.13	742.	0.40	12.00	0.03	0.40
50669	2330	4280	0	260	7	40	23	0.14	1.10	164	140	52	24	16	7.3	11	144	1.5	0.03	0.02	53.	0.30	1.00	0.30	0.45
50769	115	11430	2	360	22	18[illegible]	64	2.38	2.80	1312	144	****	1168	200	8.8	5	129	3.3	0.22	0.07	53.	0.30	1.00	0.30	0.45
51569	2015	4380	****	127	16	54	35	0.28	1.42	352	284	164	68	64	7.1	21	168	2.3	0.08	0.03	169.	0.25	0.75	0.33	0.60
60869	2100	400	0	0	5	215	71	2.95	7.60	6568	192	80	6376	660	8.1	5	88	1.3	0.35	0.27	181.	1.20	4.25	0.28	1.05
61269	520	20000	250	7750	12	114	44	0.06	3.02	5088	220	100	4868	736	8.2	5	96	1.6	0.10	0.06	80.	0.35	0.50	0.70	1.10
61769	1200	1000	350	250	11	64	17	0.42	1.20	944	276	144	668	120	7.7	7	129	4.5	0.35	0.08	72.	0.80	3.50	0.26	2.80
62369	2350	3750	150	250	16	213	58	1.77	15.10	5812	108	24	5704	576	8.2	4	92	1.3	0.65	0.50	156.	0.35	3.50	0.10	1.80
62469	1225	3500	700	750	11	73	28	0.51	1.88	1180	236	180	994	148	7.5	8	120	3.7	0.25	0.07	9.	0.65	1.00	0.65	2.40
73169	600	750	50	0	19	138	***	0.46	1.95	1796	320	244	1476	200	8.9	4	83	3.8	0.65	0.17	256.	0.20	0.50	0.40	0.10
73169	755	530	150	130	9	62	24	0.19	1.00	848	272	248	576	104	8.2	4	83	5.7	0.85	0.15	256.	0.20	0.50	0.40	0.10
81469	810	2300	200	1100	11	85	***	0.51	1.10	200	60	44	140	36	7.8	4	77	5.8	0.70	0.12	336.	0.85	5.00	0.17	0.25
81469	1025	700	40	100	26	184	***	0.64	1.83	1020	232	124	788	166	7.2	9	163	6.0	0.70	0.09	336.	0.85	5.00	0.17	0.25

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 2

		BACTERIOLOGICAL NUMBER/ML				ORGANIC MG/L		NUTRIENT MG/L		SOLIDS MG/L					OTHER MG/L										
DATE	TIME	T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* CONC	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
100968	610	23	****	51	2	***	***	*****	*****	100	60	20	40	****	7.0	71	***	1.9	0.53	0.28	103.	1.00	3.75	0.27	1.30
100968	625	7	****	125	3	***	***	*****	*****	108	52	12	56	52	7.2	71	***	2.2	0.56	0.25	103.	1.00	3.75	0.27	1.30
100968	640	10	****	801	3	***	***	*****	*****	84	40	32	44	****	7.3	71	***	2.4	0.60	0.25	103.	1.00	3.75	0.27	1.30
101668	1810	111	****	40	7	***	***	*****	*****	176	68	12	108	36	8.2	10	***	4.2	0.27	0.06	163.	0.70	2.50	0.28	1.10
101668	1825	*******	****	25	4	***	***	*****	*****	152	68	36	84	8	8.1	7	***	4.4	0.29	0.07	163.	0.70	2.50	0.28	1.10
101668	1940	*******	****	13	4	***	***	*****	*****	96	28	****	68	56	8.0	7	***	5.7	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	1955	*******	****	43	5	***	***	*****	*****	120	72	64	48	24	8.1	7	***	5.9	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	2010	*******	****	5	3	***	***	*****	*****	154	110	10	44	20	8.1	7	***	6.2	0.35	0.06	163.	0.70	2.50	0.28	1.10
101668	2025	*******	****	0	5	***	***	*****	*****	136	98	30	38	18	7.9	7	***	6.4	0.35	0.05	163.	0.70	2.50	0.28	1.10
101668	2040	*******	****	*******	4	***	***	*****	*****	138	84	46	54	4	7.7	7	***	6.7	0.35	0.05	163.	0.70	2.50	0.28	1.10
22069	1315	87	0	30	6	53	24	0.30	0.40	188	92	72	96	24	7.4	4	91	6.3	0.51	0.08	772.	0.40	8.50	0.05	0.40
22069	1335	62	0	5	7	53	30	0.90	0.60	244	104	56	140	60	7.4	5	116	6.6	0.53	0.08	772.	0.40	8.50	0.05	0.40
22069	1415	125	0	2	6	53	18	0.90	0.60	220	100	40	120	60	7.4	6	122	7.3	0.58	0.08	772.	0.40	8.50	0.05	0.40
32369	1000	200	1	0	2	22	14	1.68	1.00	280	40	20	240	60	7.4	2	67	13.0	1.35	0.10	375.	0.11	1.00	0.11	0.40
32369	1100	100	1	0	2	24	19	1.47	1.35	660	40	12	620	60	7.5	2	59	14.0	1.65	0.12	375.	0.11	1.00	0.11	0.40
32369	1200	40	1	0	2	24	19	1.26	1.35	600	60	20	540	40	7.2	2	65	15.0	1.75	0.12	375.	0.11	1.00	0.11	0.40
50769	15	4280	6	160	12	52	28	2.84	0.70	120	92	28	28	0	7.4	6	95	2.3	0.08	0.03	53.	0.30	1.00	0.30	0.45
50769	250	4280	0	40	19	20	12	0.70	0.80	172	60	20	112	24	7.0	4	67	4.8	0.41	0.09	53.	0.30	1.00	0.30	0.45
51569	2030	1320	****	11	15	21	36	0.17	0.74	520	68	40	452	140	7.3	3	74	1.3	0.28	0.22	574.	0.25	1.58	0.16	0.60
61769	1215	1530	1050	0	8	68	21	0.22	1.29	332	212	172	120	108	7.4	4	92	5.0	0.40	0.08	71.	1.40	3.50	0.40	2.80
62469	1005	8000	1700	0	7	46	12	0.74	0.80	560	164	108	396	64	7.3	3	56	0.8	0.25	0.31	10.	1.20	1.75	0.69	2.40
73169	545	250	200	250	6	27	***	0.60	0.25	216	204	176	12	12	7.3	4	58	3.8	0.54	0.14	255.	0.15	1.00	0.15	0.10
73169	810	750	50	0	6	29	***	0.31	0.23	216	196	176	20	14	7.2	5	76	6.2	0.85	0.14	256.	0.15	1.00	0.15	0.10
81469	740	600	40	100	12	94	***	3.61	1.50	152	100	68	52	4	6.8	5	116	5.7	0.25	0.04	336.	0.85	4.50	0.18	0.25
81569	730	400	40	50	5	36	***	0.58	0.52	128	80	44	48	12	7.0	2	48	3.5	1.23	0.35	20.	0.25	0.75	0.33	0.45
81569	925	200	100	4400	2	36	***	0.28	0.90	128	72	72	56	16	7.1	2	44	5.4	2.52	0.47	20.	0.25	0.75	0.33	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 3

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L									
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
92368	2100	50	****	30	***	***	***	*****	*****	108	60	32	48	24	7.2	15	***	0.0	0.0	0.0	34.	0.25	0.75	0.33	0.15
92368	2130	30	****	50	***	***	***	*****	*****	72	40	8	32	28	7.2	15	***	0.5	0.13	0.26	34.	0.25	0.75	0.33	0.15
92368	2200	10	****	30	***	***	***	*****	*****	56	32	12	24	8	7.2	15	***	1.0	0.25	0.25	34.	0.25	0.75	0.33	0.15
92368	2230	30	****	20	***	***	***	*****	*****	68	48	40	20	16	7.2	15	***	1.5	0.33	0.22	34.	0.25	0.75	0.33	0.15
92368	2300	15	****	10	***	***	***	*****	*****	60	40	28	20	8	7.2	15	***	2.0	0.40	0.20	34.	0.25	0.75	0.33	0.15
92368	2330	10	****	0	***	***	***	*****	*****	48	32	24	16	4	7.2	15	***	2.5	0.45	0.18	34.	0.25	0.75	0.33	0.15
100968	550	*******	****	437	4	***	***	*****	*****	192	80	40	112	64	7.1	71	***	1.3	0.35	0.26	58.	1.00	4.50	0.22	1.30
100968	605	50	****	560	4	***	***	*****	*****	196	80	12	116	56	7.2	71	***	1.6	0.46	0.29	58.	1.00	4.50	0.22	1.30
100968	620	*******	****	1665	3	***	***	*****	*****	160	68	24	92	48	7.2	71	***	1.8	0.50	0.28	58.	1.00	4.50	0.22	1.30
100968	635	53	****	1873	3	***	***	*****	*****	120	40	28	80	24	7.2	71	***	2.1	0.53	0.25	58.	1.00	4.50	0.22	1.30
101668	1840	*******	****	0	4	***	***	*****	*****	205	116	54	89	18	8.0	7	***	4.4	0.24	0.05	163.	0.70	2.50	0.28	1.10
101668	1855	*******	****	0	4	***	***	*****	*****	****	****	****	****	****	8.0	7	***	4.7	0.25	0.05	163.	0.70	2.50	0.28	1.10
101668	1910	*******	****	1	3	***	***	*****	*****	136	88	22	48	26	7.9	7	***	4.9	0.25	0.05	163.	0.70	2.50	0.28	1.10
101668	1925	*******	****	0	3	***	***	*****	*****	****	****	****	****	****	7.9	7	***	5.2	0.25	0.05	163.	0.70	2.50	0.28	1.10
101668	1940	*******	****	0	3	***	***	*****	*****	126	98	38	28	2	7.9	7	***	5.4	0.25	0.05	163.	0.70	2.50	0.28	1.10
101668	1955	*******	****	27	3	***	***	*****	*****	****	****	****	****	****	7.9	7	***	5.7	0.25	0.04	163.	0.70	2.50	0.28	1.10
101668	2005	*******	****	*******	3	***	***	*****	*****	128	96	30	32	2	7.9	7	***	5.8	0.25	0.04	163.	0.70	2.50	0.28	1.10
22069	1330	25	0	150	5	52	20	0.98	0.60	212	92	32	120	20	7.4	6	125	6.5	0.48	0.07	110.	0.45	26.00	0.02	0.40
22069	1410	50	0	2	4	40	18	0.84	0.60	160	80	20	80	12	7.4	5	117	7.2	0.56	0.08	110.	0.45	26.00	0.02	0.40
22069	1450	0	0	5	3	36	21	0.70	0.65	224	112	104	112	16	7.3	7	121	7.8	0.59	0.08	110.	0.45	26.00	0.02	0.40
22069	1530	25	0	2	4	36	22	0.84	0.60	180	120	48	60	12	7.1	7	127	8.5	0.60	0.07	110.	0.45	26.00	0.02	0.40
32369	1000	70	1	0	2	28	18	1.26	1.78	380	80	20	300	60	7.3	3	86	13.0	1.45	0.11	742.	0.40	12.00	0.03	0.40
32369	1400	70	1	0	2	12	18	1.33	1.25	400	80	20	320	80	7.2	3	70	17.0	2.35	0.14	742.	0.40	12.00	0.03	0.40
[illegible]	1000	360	0	60	9	100	28	4.41	4.80	396	232	84	164	64	7.2	14	183	8.5	0.30	0.04	467.	3.00	29.00	0.10	0.40
[illegible]	1100	260	0	47	6	68	21	1.82	2.80	248	160	92	88	28	7.2	7	140	9.5	0.40	0.04	467.	3.00	29.00	0.10	0.40
41369	1200	160	0	65	5	64	17	2.80	3.60	180	140	40	40	20	7.2	7	142	10.5	0.50	0.05	467.	3.00	29.00	0.10	0.40
41669	2330	480	4	100	9	72	31	3.64	2.60	556	160	88	396	56	7.2	6	119	1.8	0.35	0.19	82.	0.50	10.25	0.05	0.70
41769	130	360	32	23	8	92	***	2.87	2.40	312	160	72	152	48	7.2	6	96	3.8	0.90	0.24	82.	0.50	10.25	0.05	0.70
50669	2345	10000	53	920	18	104	32	3.78	2.10	452	136	64	316	120	6.7	8	114	1.8	0.04	0.02	79.	0.25	0.25	1.00	0.45
50769	130	8000	33	411	11	36	26	3.78	2.80	272	80	20	192	56	6.8	4	113	3.5	0.26	0.07	79.	0.25	0.25	1.00	0.45
51569	2130	7550	****	343	12	39	31	0.45	1.30	264	144	48	120	36	7.0	9	139	3.5	0.10	0.03	169.	0.25	0.75	0.33	0.60
52469	1845	*******	****	*******	***	9	3	0.20	0.10	****	****	****	****	****	7.9	30	299	0.3	0.15	0.50	12.	0.20	1.50	0.13	0.60
52469	1925	*******	****	*******	***	15	15	0.13	0.10	****	****	****	****	****	7.9	29	296	0.9	0.22	0.24	12.	0.20	1.50	0.13	0.60
52469	2005	*******	****	*******	***	46	12	0.17	0.10	****	****	****	****	****	8.2	30	298	1.6	0.25	0.16	12.	0.20	1.50	0.13	0.60
60869	2015	200	20	60	5	136	15	1.00	2.36	1052	180	88	872	136	7.3	5	108	0.5	0.31	0.62	181.	1.20	4.25	0.28	1.05
60869	2130	100	60	70	6	49	13	1.09	2.20	304	124	116	180	36	7.2	6	112	1.8	0.35	0.19	181.	1.20	4.25	0.28	1.05
61369	2030	137500	750	250	4	58	21	0.98	2.15	788	72	16	716	136	7.1	3	69	0.3	0.25	0.83	40.	0.10	1.00	0.10	1.75
61369	2110	200000	1700	1000	2	61	20	0.80	2.64	520	164	112	460	60	7.1	4	77	0.9	0.51	0.57	40.	0.10	1.00	0.10	1.75
61369	2150	132500	1500	750	4	42	18	0.90	2.68	412	164	60	248	136	7.0	4	90	1.6	0.54	0.34	40.	0.10	1.00	0.10	1.75
62369	2300	5500	1750	1500	15	117	38	1.67	3.02	3760	236	108	3524	260	7.3	9	153	0.5	0.65	1.30	156.	0.35	3.50	0.10	1.80
62469	1105	4750	50	2750	9	51	19	0.72	2.12	296	240	180	56	24	7.3	6	102	2.3	0.25	0.11	9.	0.65	1.00	0.65	2.40
62469	20	5750	500	3250	12	82	32	1.62	3.02	952	240	196	712	172	7.2	10	158	1.6	0.65	0.36	156.	0.35	3.50	0.10	1.80
62469	140	6000	1050	3250	12	59	22	1.69	3.02	424	120	76	304	64	7.1	7	111	3.2	0.65	0.20	156.	0.35	3.50	0.10	1.80
73169	445	4000	50	3600	10	60	18	0.22	0.92	552	172	140	380	96	7.2	4	65	2.5	0.53	0.21	256.	0.20	0.50	0.40	0.10
73169	545	1800	0	3800	7	33	18	0.29	0.78	312	272	256	40	20	7.2	4	67	3.5	0.63	0.18	256.	0.20	0.50	0.40	0.10
73169	645	750	50	1400	7	33	22	0.20	0.74	168	120	112	48	16	7.1	4	63	4.5	0.80	0.18	256.	0.20	0.50	0.40	0.10
81469	715	2000	100	650	22	186	***	0.67	1.85	804	80	0	724	32	7.0	11	130	4.8	0.63	0.13	336.	0.85	5.00	0.17	0.25
81469	800	700	640	450	20	137	***	1.13	1.04	416	300	168	116	32	7.0	15	192	5.6	0.70	0.13	336.	0.85	5.00	0.17	0.25

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 4

DATE	TIME	BACTERIOLOGICAL NUMBER/ML T. COL.	F.COL.	F.STREP.	ORGANIC MG/L BOD	COD	TOC	NUTRIENT MG/L N	PO4	SOLIDS MG/L TOTAL	DS	VDS	SS	VSS	OTHER MG/L PH	CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
110268	1445	4400000	60	20	16	96	***	*****	*****	402	236	66	166	18	7.2	17	***	3.0	0.81	0.27	3°6.	0.35	4.30	0.08	0.35
110268	1515	5000000	80	80	8	50	***	*****	*****	299	224	6"	75	3	7.3	10	***	3.5	C.81	0.23	398.	0.35	4.30	0.08	0.35
110268	1545	*******	40	40	10	76	***	*****	*****	280	222	90	58	6	7.6	10	***	4.0	0.81	0.20	398.	0.35	4.30	0.08	0.35
110268	1615	*******	120	0	9	68	***	*****	*****	265	187	64	78	8	7.4	10	***	4.5	0.81	0.18	398.	0.35	4.30	0.08	0.35
110268	1645	*******	60	20	8	64	***	*****	*****	286	150	58	136	34	7.6	10	***	5.0	0.81	0.16	398.	0.35	4.30	0.08	0.35
111068	1030	160	0	40	29	64	***	0.70	0.70	654	568	190	86	4	7.3	3	***	1.8	0.15	0.08	175.	0.30	2.75	0.11	1.05
111068	1100	600	0	70	16	64	***	0.70	0.70	164	134	78	30	6	7.4	3	***	2.3	0.20	0.09	175.	0.30	2.75	0.11	1.05
111068	1130	440	0	120	11	72	***	0.63	0.70	220	162	80	58	0	7.5	3	***	2.8	0.25	0.09	175.	0.30	2.75	0.11	1.05
111568	130	3280	0	130	16	104	32	1.12	1.55	983	733	140	250	4	7.1	***	***	2.3	0.20	0.09	80.	0.50	6.00	0.08	1.10
111568	145	360C	7	30	16	104	27	1.12	1.55	594	326	60	268	28	7.3	***	***	2.5	0.25	0.10	80.	0.50	6.00	0.08	1.10
111568	215	3200	0	130	13	92	27	0.98	1.00	411	134	26	277	20	7.4	***	***	3.C	0.39	0.13	80.	0.50	6.00	0.08	1.10
11156d	245	3880	0	8C	10	92	34	0.98	1.00	384	124	32	360	24	7.6	***	***	3.5	0.56	0.16	80.	0.50	6.00	0.08	1.10
112668	1210	2360	0	10	32	160	73	*****	*****	****	****	****	****	****	7.3	***	***	1.7	0.11	0.06	259.	0.25	8.50	0.03	0.90
112668	1220	1840	0	90	27	196	74	*****	*****	640	280	80	360	200	7.5	8	***	1.8	0.12	0.07	259.	0.25	8.50	0.03	0.90
112668	1250	1160	0	40	31	124	63	*****	*****	820	172	52	648	440	7.4	8	***	2.3	0.14	0.06	259.	0.25	8.50	0.03	0.90
112668	1320	4080	5	60	38	116	75	*****	*****	****	****	****	****	****	7.3	***	***	2.8	0.15	0.05	259.	0.25	8.50	0.03	0.90
112668	1350	3400	0	80	35	136	55	*****	*****	284	104	32	180	120	7.3	8	***	3.3	0.15	0.05	259.	0.25	8.50	0.03	0.90
112668	1420	40	0	10	32	176	58	*****	*****	****	****	****	****	****	7.2	***	***	3.8	0.17	0.05	259.	0.25	8.50	0.03	0.90
112668	1450	720	0	80	9	132	41	*****	*****	408	160	40	148	128	7.5	***	***	4.3	0.19	0.04	259.	0.25	8.50	0.03	0.90
121868	1325	1480	0	310	10	160	58	1.20	0.55	520	200	100	320	232	7.9	11	160	1.4	0.21	0.15	511.	0.71	9.00	0.08	0.30
121868	1340	120	C	0	7	186	40	1.20	0.55	420	168	80	252	132	8.0	9	157	1.7	0.22	0.13	511.	0.71	9.00	0.08	0.30
121868	1355	880	0	100	3	46	63	1.20	0.55	420	180	80	240	108	7.9	9	157	1.9	0.24	0.13	511.	0.71	9.00	0.08	0.30
121869	141C	480	0	7C	5	86	41	1.20	0.55	440	200	80	240	80	7.9	9	163	2.2	0.24	0.11	511.	0.71	9.00	0.08	0.30
121868	1425	600	0	90	***	***	***	*****	*****	****	****	****	****	****	****	***	***	2.4	0.24	0.10	511.	0.71	9.00	0.08	0.30
122768	630	0	0	5	13	296	69	*****	*****	1092	218	88	847	130	7.7	7	131	4.5	0.73	0.16	124.	0.14	2.00	0.07	0.50
122768	ECC	1700	0	30	4	192	23	*****	*****	384	238	14	146	58	7.6	11	174	6.0	0.75	0.13	124.	0.14	2.00	0.07	0.50
122768	730	20	0	25	5	180	26	*****	*****	447	250	46	197	33	7.6	18	154	5.5	0.75	0.14	124.	0.14	2.00	0.07	0.50
11569	600	280	0	90	29	144	59	0.0	4.00	1244	518	114	726	114	7.5	40	344	0.0	0.C	0.0	457.	1.10	3.25	0.34	0.30
11569	620	400	0	10	27	176	59	0.0	2.00	1168	654	94	514	94	7.3	41	403	0.3	0.03	0.10	457.	1.10	3.25	0.34	0.30
11569	640	720	0	10	25	212	71	3.00	1.00	812	462	72	350	112	7.3	55	310	0.7	0.07	0.10	457.	1.10	3.25	0.34	0.30
11569	700	160	0	20	19	112	55	0.0	1.00	****	****	****	****	****	7.3	45	251	1.0	0.10	0.10	457.	1.10	3.25	0.34	0.30
11569	720	640	0	35	18	60	41	3.00	1.00	****	****	****	****	****	7.4	37	228	1.3	0.12	0.09	457.	1.10	3.25	0.34	0.30
11569	740	440	0	65	17	76	28	1.00	1.00	606	348	118	258	54	7.5	48	244	1.7	0.13	0.08	457.	1.10	3.25	0.34	0.30
22069	2130	125	0	15	4	36	15	1.61	0.30	368	320	132	48	8	7.5	30	301	14.5	0.65	0.04	772.	0.40	8.50	0.05	0.40
41369	500	750	3	27	25	240	74	3.36	3.80	848	328	64	520	192	7.2	9	225	3.3	0.20	C.06	470.	2.75	27.00	0.10	0.40
41369	530	3500	11	80	25	236	72	2.94	2.80	1050	492	120	560	156	7.3	14	380	3.8	0.23	0.06	470.	2.75	27.00	0.10	0.40
41369	630	5000	9	140	25	220	77	2.80	2.40	740	400	88	340	92	7.3	13	299	4.8	0.26	0.05	470.	2.75	27.00	0.10	0.40
50769	45	8000	4	200	21	92	46	3.22	1.30	1304	928	180	376	176	7.0	25	694	2.8	0.15	0.05	53.	0.30	1.00	0.30	0.45
50769	225	12000	4	280	8	48	24	1.40	0.60	424	208	48	216	76	7.2	5	140	4.4	0.37	0.08	53.	0.30	1.00	0.30	0.45
51569	2105	7290	****	10	18	14	26	0.12	0.80	176	148	20	176	17	7.2	4	124	1.8	0.30	0.17	574.	0.25	1.58	0.16	0.60
60869	2045	0	0	115	5	120	27	0.0	0.96	744	96	40	648	156	7.8	4	94	3.3	0.55	0.17	180.	1.25	2.75	0.46	1.05
61269	445	10000	250	4500	8	52	22	0.38	0.64	564	196	76	368	44	8.1	5	95	2.0	0.45	0.23	69.	0.55	12.00	0.05	1.10
73169	530	2500	300	250	8	39	21	0.18	0.36	468	284	244	184	32	7.5	3	76	3.5	C.48	0.14	256.	0.15	1.00	0.15	0.10
81569	755	0	40	250C	5	61	***	0.19	0.46	828	356	120	472	80	7.4	3	71	3.9	1.33	0.34	20.	0.25	0.75	0.33	0.45
81569	940	0	100	2300	3	66	***	0.25	0.77	1052	124	80	928	88	7.7	3	77	5.7	2.55	C.45	20.	0.25	0.75	0.33	0.45

* MICRCMHCS/CM

**** NO CATA

TABLE M-2 — Continued

TEST AREA NO. 5

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L		TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND								
111068	945	680	3	310	18	120	***	0.70	1.55	76	36	****	40	****	6.9	***	***	1.0	0.13	0.13	221.	0.45	5.00	0.09	1.05
111068	1015	120	0	220	38	120	***	0.70	1.55	72	34	****	38	****	6.8	***	***	1.5	0.18	0.12	221.	0.45	5.00	0.09	1.05
111068	1045	1240	10	240	40	124	***	0.56	1.65	106	66	42	40	26	6.8	***	***	2.0	0.23	0.12	221.	0.45	5.00	0.09	1.05
111068	1115	400	40	170	39	128	***	0.56	1.65	170	136	36	34	22	6.8	***	***	2.5	0.28	0.11	221.	0.45	5.00	0.09	1.05
111068	1145	480	40	180	20	104	***	0.63	1.65	166	92	26	74	56	6.7	***	***	3.0	0.33	0.11	221.	0.45	5.00	0.09	1.05
111068	1215	560	10	210	32	104	***	0.63	1.65	222	184	102	38	12	6.6	***	***	3.5	0.36	0.10	221.	0.45	5.00	0.09	1.05
111068	1245	320	30	160	20	72	***	0.42	1.25	170	118	40	52	36	6.6	***	***	4.0	0.39	0.10	221.	0.45	5.00	0.09	1.05
111568	130	4040	7	50	42	148	80	1.20	1.40	290	115	31	135	71	7.1	***	***	5.0	0.48	0.10	4.	1.60	10.50	0.15	1.10
111568	145	3680	0	30	41	148	85	1.20	1.40	304	178	72	126	38	7.1	***	***	5.3	0.56	0.11	4.	1.60	10.50	0.15	1.10
111568	200	3200	7	40	43	164	95	1.20	1.40	216	172	80	44	9	7.0	***	***	5.5	0.65	0.12	4.	1.60	10.50	0.15	1.10
111568	215	3760	74	50	38	164	76	1.20	1.40	304	162	66	142	34	7.0	***	***	5.8	0.75	0.13	4.	1.60	10.50	0.15	1.10
111568	230	3200	47	50	35	116	81	0.60	1.30	224	160	72	64	20	7.2	***	***	6.0	0.85	0.14	4.	1.60	10.50	0.15	1.10
111568	245	3840	21	40	32	116	93	0.60	1.30	198	108	52	90	20	6.9	***	***	6.3	0.95	0.15	4.	1.60	10.50	0.15	1.10
111568	300	2800	7	50	33	116	49	0.60	1.30	158	116	64	42	4	6.5	***	***	6.5	1.05	0.16	4.	1.60	10.50	0.15	1.10
112668	1630	80	0	100	40	182	88	*****	*****	236	112	32	124	64	6.9	5	125	5.3	0.33	0.06	259.	0.25	8.50	0.03	0.90
112668	1700	160	5	90	36	156	107	*****	*****	****	****	****	****	****	6.9	***	***	5.8	0.35	0.06	259.	0.25	8.50	0.03	0.90
112668	1730	120	0	30	40	222	69	*****	*****	192	80	40	112	52	6.9	4	115	6.3	0.40	0.06	259.	0.25	8.50	0.03	0.90
112668	1800	80	0	90	36	64	62	*****	*****	****	****	****	****	****	6.8	***	***	6.8	0.45	0.07	259.	0.25	8.50	0.03	0.90
112668	1830	160	0	120	36	172	59	*****	*****	****	****	****	****	****	6.8	***	***	7.3	0.50	0.07	259.	0.25	8.50	0.03	0.90
112668	1900	0	0	10	32	324	57	*****	*****	128	48	8	80	68	6.8	5	127	7.8	0.55	0.07	259.	0.25	8.50	0.03	0.90
112668	1930	80	5	40	31	224	133	*****	*****	140	40	16	100	60	7.1	4	112	8.3	0.58	0.07	259.	0.25	8.50	0.03	0.90
121868	1240	2200	50	170	34	250	103	2.40	0.65	456	200	120	256	96	7.3	11	126	0.7	0.15	0.21	511.	0.71	9.00	0.08	0.30
121868	1255	40	5	0	28	158	91	2.40	0.65	352	160	80	192	72	7.2	11	111	0.5	0.18	0.20	511.	0.71	9.00	0.08	0.30
121868	1310	0	0	0	24	198	81	1.40	0.75	240	100	60	140	80	7.2	11	108	1.2	0.19	0.16	511.	0.71	9.00	0.08	0.30
121868	1325	40	0	0	23	222	82	1.40	0.75	228	108	6	120	80	7.2	11	100	1.4	0.21	0.15	511.	0.71	9.00	0.08	0.30
121868	1340	0	0	40	21	182	70	0.0	1.40	172	72	40	100	40	7.4	11	100	1.7	0.22	0.13	511.	0.71	9.00	0.08	0.30
121868	1455	0	0	0	***	***	***	*****	*****	****	****	****	****	****	****	***	100	2.9	0.24	0.08	511.	0.71	9.00	0.08	0.30
122768	230	3000	0	45	9	226	30	*****	*****	242	112	40	130	2	7.2	4	86	0.8	0.53	0.66	144.	0.12	1.00	0.12	0.50
122768	245	4020	0	15	13	274	38	*****	*****	****	****	****	****	****	7.3	2	65	1.0	0.59	0.59	144.	0.12	1.00	0.12	0.50
122768	300	3560	0	5	5	174	23	*****	*****	276	136	116	140	****	7.4	1	51	1.3	0.65	0.50	144.	0.12	1.00	0.12	0.50
122768	315	5120	0	20	5	218	18	*****	*****	166	62	14	104	2	7.2	2	52	1.5	0.68	0.45	144.	0.12	1.00	0.12	0.50
122768	330	4600	0	30	3	192	16	0.56	*****	****	****	****	****	****	7.1	2	51	1.8	0.70	0.39	144.	0.12	1.00	0.12	0.50
122768	345	3080	0	15	3	184	17	0.42	*****	****	****	****	****	****	7.0	2	49	2.0	0.73	0.37	144.	0.12	1.00	0.12	0.50
122768	400	3440	0	25	2	284	11	0.98	*****	636	256	54	380	74	7.4	3	51	2.3	0.75	0.33	144.	0.12	1.00	0.12	0.50
122768	840	3200	0	35	7	224	38	0.70	*****	344	94	36	250	28	7.6	2	***	6.9	0.82	0.12	144.	0.12	1.00	0.12	0.50
41769	150	*******	209	755	23	124	48	3.64	1.10	192	112	64	80	20	7.0	2	68	3.6	0.98	0.27	67.	0.50	13.50	0.04	0.70
41769	220	*******	29	675	8	32	21	0.91	0.50	40	20	20	20	16	6.8	2	62	4.1	1.02	0.25	67.	0.50	13.50	0.04	0.70
41769	250	180	0	91	0	28	24	0.84	0.60	92	80	48	12	0	6.7	3	68	4.6	1.04	0.23	67.	0.50	13.50	0.04	0.70
61369	2110	215000	250	0	4	48	11	0.0	0.58	224	140	68	84	36	7.1	4	59	1.2	0.56	0.47	40.	0.30	1.25	0.26	1.75
61369	2150	22500	250	250	2	33	11	0.02	0.53	284	204	152	80	48	7.2	4	73	1.8	0.59	0.33	40.	0.30	1.25	0.26	1.75
61369	2230	40000	50	0	2	31	10	0.01	0.50	168	144	116	24	24	7.2	4	70	2.5	0.60	0.24	40.	0.30	1.25	0.26	1.75
61769	1130	750	1300	1500	10	110	30	0.0	0.72	380	84	0	296	64	7.7	2	64	4.3	0.43	0.10	72.	1.35	3.25	0.42	2.80
62469	945	9250	1050	0	11	73	26	0.30	0.55	224	132	80	92	36	7.3	20	99	0.8	0.11	0.14	10.	0.65	1.75	0.37	2.40
73169	430	40000	0	0	17	135	28	0.68	0.68	534	284	214	250	104	6.8	11	84	2.5	0.40	0.16	880.	0.20	1.25	0.16	0.10
81469	150	*******	400	1200	***	347	***	1.33	1.25	482	138	104	344	152	6.6	9	128	0.1	0.20	2.00	331.	0.75	4.75	0.16	0.25
81469	250	*******	300	3700	***	285	***	1.30	0.90	360	208	192	152	116	6.7	10	130	1.1	0.20	0.18	331.	0.75	4.75	0.16	0.25
81469	350	*******	1200	850	27	251	***	1.15	0.83	212	160	80	52	48	6.6	9	126	2.1	0.20	0.10	331.	0.75	4.75	0.16	0.25
81469	845	100	100	600	16	160	***	0.51	0.71	272	188	132	84	56	7.2	6	112	7.0	0.25	0.04	331.	0.75	4.75	0.16	0.25
81569	410	6500	40	1400	18	155	***	0.33	0.46	336	132	104	204	128	7.3	3	74	0.4	0.26	0.65	21.	0.25	5.00	0.05	0.45
81569	1045	500	180	*******	12	75	***	0.04	1.01	216	152	104	64	36	7.2	3	72	7.0	2.55	0.36	21.	0.25	5.00	0.05	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 6

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L		TIME SINCE START	ANT. AMOUNT	ANT. AVERAGE INTENSITY	TIME SINCE ANT. EVENT	AMOUNT OF ANT EVENT	DURATION OF ANT. EVENT	AVERAGE INTENSITY ANT. EVENT	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND	(HRS)	(IN.)	(IN./HR.)	(HRS.)	(IN.)	(HRS.)	(IN./HR.)	
12969	1000	40	0	10	8	133	42	0.98	1.39	474	154	68	320	38	7.4	5	101	2.3	0.45	0.20	331.	0.45	4.75	0.10	0.20
22069	1510	311	0	7	6	90	30	0.80	0.90	328	160	60	168	48	7.5	6	147	8.2	0.66	0.08	135.	0.65	6.50	0.02	0.40
32369	800	150	0	0	5	80	39	1.33	0.88	260	80	28	180	80	7.3	5	94	10.5	1.15	0.11	718.	0.25	11.00	0.02	0.40
32369	1500	3200	1	0	6	68	26	1.40	0.88	200	100	40	100	60	7.3	5	118	17.5	2.25	0.13	718.	0.25	11.00	0.02	0.40
50769	230	20000	9	1000	16	64	30	1.12	0.80	228	168	60	60	40	7.4	12	144	4.5	0.38	0.08	53.	0.30	1.00	0.30	0.45
50769	530	10000	0	450	14	48	42	0.98	0.80	172	152	64	20	8	7.0	12	149	7.5	0.43	0.06	53.	0.30	1.00	0.30	0.45
51569	2150	17600	****	100	15	39	37	0.17	0.74	284	192	100	92	40	7.7	13	138	3.8	0.80	0.21	692.	1.05	4.25	0.25	0.60
61269	330	55000	750	6500	11	122	42	0.59	0.87	516	192	64	324	92	8.0	10	95	1.0	0.18	0.18	69.	0.60	12.00	0.05	1.10
61769	840	36000	4700	1250	15	102	43	0.27	0.80	516	160	100	356	136	7.7	8	94	1.4	0.28	0.20	72.	1.35	3.25	0.42	2.80
61769	1040	11000	1550	1000	17	106	33	0.26	0.76	300	168	80	132	40	7.5	11	135	3.4	0.39	0.11	72.	1.35	3.25	0.42	2.80
61769	1250	10000	700	750	21	109	36	0.32	0.78	392	284	184	108	36	7.3	13	139	5.6	0.45	0.08	72.	1.35	3.25	0.42	2.80
62369	2300	9500	1750	1250	14	95	12	0.16	1.05	480	200	104	280	40	7.5	9	91	1.8	0.65	0.36	154.	0.45	4.50	0.10	1.80
73169	740	4000	200	500	9	79	20	0.23	0.58	124	56	8	68	68	7.4	7	73	5.7	0.75	0.13	880.	0.20	1.25	0.16	0.10
81569	540	300	80	5900	13	145	***	0.29	0.76	528	88	24	440	52	7.4	5	84	1.9	0.75	0.39	21.	0.25	5.00	0.05	0.45
81569	740	100	60	3000	7	74	***	0.21	0.44	304	112	52	192	72	7.4	3	62	3.9	1.72	0.44	21.	0.25	5.00	0.05	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 7

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L			TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* CONC								
92368	1950	285	****	60	***	***	***	*****	*****	168	120	72	48	0	7.2	29	***	1.1	0.62	0.56	27.	0.15	0.50	0.30	0.15
92368	2020	120	****	70	***	***	***	*****	*****	160	120	52	40	0	7.2	15	***	1.6	0.77	0.48	27.	0.15	0.50	0.30	0.15
92368	2050	125	****	40	***	***	***	*****	*****	180	120	60	60	0	7.4	22	***	2.1	0.87	0.41	27.	0.15	0.50	0.30	0.15
92368	2120	995	****	70	***	***	***	*****	*****	80	40	****	40	32	7.4	22	***	2.6	0.93	0.36	27.	0.15	0.50	0.30	0.15
92368	2150	65	****	240	***	***	***	*****	*****	56	32	32	24	16	7.4	22	***	3.1	0.98	0.32	27.	0.15	0.50	0.30	0.15
92368	2220	70	****	90	***	***	***	*****	*****	48	24	****	24	0	7.4	15	***	3.6	1.05	0.29	27.	0.15	0.50	0.30	0.15
100568	1030	*******	****	13	***	***	***	*****	*****	****	****	****	****	****	7.2	***	***	3.0	0.70	0.23	267.	1.70	9.80	0.17	0.85
100568	1100	*******	****	17	***	***	***	*****	*****	****	****	****	****	****	7.3	***	***	3.5	0.90	0.26	267.	1.70	9.80	0.17	0.85
100568	1130	*******	****	15	***	***	***	*****	*****	****	****	****	****	****	7.4	***	***	4.0	0.95	0.24	267.	1.70	9.80	0.17	0.85
100568	1200	*******	****	14	***	***	***	*****	*****	****	****	****	****	****	7.3	***	***	4.5	1.00	0.22	267.	1.70	9.80	0.17	0.85
100568	1230	*******	****	21	***	***	***	*****	*****	****	****	****	****	****	7.3	***	***	5.0	1.00	0.20	267.	1.70	9.80	0.17	0.85
100568	1300	*******	****	1	***	***	***	*****	*****	****	****	****	****	****	7.3	***	***	5.5	1.00	0.18	267.	1.70	9.80	0.17	0.85
100968	625	37	****	151	1	***	***	*****	*****	100	40	32	60	32	7.5	71	***	2.2	0.56	0.25	103.	1.00	3.80	0.27	1.30
100968	640	23	****	175	2	***	***	*****	*****	172	60	28	112	28	7.6	71	***	2.4	0.60	0.25	103.	1.00	3.80	0.27	1.30
100968	655	11	****	145	3	***	***	*****	*****	140	32	20	108	28	7.5	71	***	2.7	0.64	0.24	103.	1.00	3.80	0.27	1.30
100968	710	21	****	113	1	***	***	*****	*****	100	20	8	80	24	7.5	71	***	2.9	0.65	0.22	103.	1.00	3.80	0.27	1.30
100968	725	10	****	140	2	***	***	*****	*****	52	32	28	20	20	7.5	71	***	3.2	0.65	0.20	103.	1.00	3.80	0.27	1.30
100968	740	13	****	123	0	***	***	*****	*****	56	24	16	32	16	7.5	71	***	3.4	0.65	0.19	103.	1.00	3.80	0.27	1.30
101668	1750	*******	****	1	15	***	***	*****	*****	424	88	66	338	54	7.8	7	***	3.8	0.23	0.06	163.	0.70	2.50	0.28	1.10
101668	1805	*******	****	0	13	***	***	*****	*****	****	****	****	****	****	7.8	7	***	4.1	0.26	0.06	163.	0.70	2.50	0.28	1.10
110268	930	*******	120	0	15	***	***	*****	*****	216	108	64	108	22	6.7	10	***	1.5	0.20	0.13	398.	0.35	4.30	0.08	0.35
110268	1000	*******	0	0	15	***	***	*****	*****	****	****	****	****	****	7.1	7	***	2.0	0.20	0.10	398.	0.35	4.30	0.08	0.35
110268	1030	*******	80	20	21	***	***	*****	*****	136	124	62	12	****	7.2	7	***	2.5	0.20	0.08	398.	0.35	4.30	0.08	0.35
22069	1230	175	0	2	6	82	23	0.70	0.60	284	144	60	140	52	7.4	19	153	5.5	0.43	0.08	772.	0.40	8.50	0.05	0.40
22069	1310	250	0	0	5	68	19	0.60	0.70	204	108	40	96	24	7.3	19	132	6.2	0.51	0.08	772.	0.40	8.50	0.05	0.40
22069	1350	75	0	0	5	61	21	0.50	0.80	220	132	44	88	16	7.3	17	129	6.8	0.54	0.08	772.	0.40	8.50	0.05	0.40
22069	1430	62	0	0	4	43	14	0.40	0.80	184	120	48	64	12	7.4	17	125	7.5	0.60	0.08	772.	0.40	8.50	0.05	0.40
32369	930	70	0	0	2	52	24	1.89	1.29	112	40	8	72	32	7.3	4	83	12.5	1.28	0.10	375.	0.11	1.00	0.11	0.40
32369	1030	100	1	0	3	52	19	1.68	1.14	180	40	40	140	60	7.3	3	72	13.5	1.50	0.11	375.	0.11	1.00	0.11	0.40
32369	1130	280	2	0	3	56	18	1.40	1.20	232	92	40	140	32	7.3	3	68	14.5	1.70	0.12	375.	0.11	1.00	0.11	0.40
41369	1035	120	0	20	5	48	17	1.40	0.50	124	84	28	40	28	7.2	4	89	8.8	0.41	0.05	470.	2.75	27.00	0.10	0.40
41369	1135	40	0	51	6	48	21	1.40	0.40	144	128	32	16	0	7.4	10	142	9.8	0.48	0.05	470.	2.75	27.00	0.10	0.40
41369	1235	40	0	43	5	48	14	1.33	0.60	52	48	0	4	0	7.0	7	114	10.8	0.50	0.05	470.	2.75	27.00	0.10	0.40
41769	220	40	0	107	11	68	25	1.82	0.60	312	88	48	224	72	7.2	3	76	4.6	0.90	0.20	82.	0.50	10.00	0.05	0.70
41769	250	20	0	115	10	88	***	1.40	0.50	224	104	72	120	68	7.2	3	73	5.1	0.90	0.18	82.	0.50	10.00	0.05	0.70
41769	320	0	4	151	10	52	26	1.26	0.50	212	92	52	120	28	7.1	3	81	5.6	0.90	0.16	82.	0.50	10.00	0.05	0.70
50769	25	15000	17	1600	17	72	26	2.74	0.70	140	100	40	40	12	6.8	5	92	2.4	0.10	0.04	53.	0.30	1.00	0.30	0.45
50769	215	6000	1	443	9	40	10	1.12	0.50	100	68	20	32	12	6.8	2	66	4.2	0.35	0.08	53.	0.30	1.00	0.30	0.45
51569	2040	5320	****	0	13	39	20	0.10	0.50	140	84	48	56	56	6.9	2	50	1.4	0.28	0.20	574.	0.25	1.60	0.16	0.60
60969	2030	50	0	25	4	65	15	0.01	0.53	148	48	48	100	36	7.3	2	60	3.0	0.56	0.19	180.	1.25	2.80	0.46	1.05
61269	420	35000	0	7750	8	33	13	0.35	0.28	136	68	28	68	16	7.7	2	52	1.6	0.26	0.16	69.	0.55	12.00	0.05	1.10
61769	1300	1250	800	1250	7	55	15	0.13	0.44	184	140	80	44	20	7.6	5	87	5.8	0.40	0.07	71.	1.40	3.50	0.40	2.80
62369	2120	15000	300	250	3	16	0	0.10	1.34	684	368	172	316	60	8.1	146	622	0.1	0.28	2.80	154.	0.40	4.50	0.09	1.80
62369	2200	12000	0	500	3	11	0	0.37	1.46	1212	1164	412	48	48	8.1	144	617	0.8	0.30	0.38	154.	0.40	4.50	0.09	1.80
62369	2240	12000	0	0	4	15	0	0.32	1.59	1228	1204	436	24	24	8.1	145	614	1.4	0.80	0.57	154.	0.40	4.50	0.09	1.80
62369	2300	8250	0	0	3	7	0	0.18	0.95	1272	1244	408	28	28	8.3	148	620	1.8	1.15	0.64	154.	0.40	4.50	0.09	1.80
81469	200	6200	0	0	5	58	***	1.34	0.88	1404	1388	504	16	16	7.5	176	649	0.0	0.0	0.0	336.	0.85	4.50	0.18	0.25
81469	300	1600	20	0	4	50	***	1.55	0.92	1472	1456	620	16	0	7.5	185	618	1.0	0.10	0.10	336.	0.85	4.50	0.18	0.25
81469	400	100	20	150	4	49	***	1.40	0.90	1248	1204	236	44	36	7.6	178	619	2.0	0.15	0.08	336.	0.85	4.50	0.18	0.25

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 8

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L					OTHER MG/L			TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND								
12969	940	280	0	80	25	405	82	1.40	2.60	978	156	38	822	266	7.6	12	119	6.7	0.47	0.07	338.	0.45	7.00	0.06	0.20
22069	1550	37	0	10	3	50	24	0.0	0.0	216	128	72	88	0	7.2	2	50	7.8	0.70	0.09	148.	0.23	13.00	0.02	0.40
32369	735	100	3	0	12	108	67	2.52	1.50	512	152	72	360	52	7.4	6	109	9.6	1.01	0.11	191.	0.08	6.00	0.01	0.40
50769	300	10000	0	211	9	72	25	1.19	0.90	224	116	56	108	28	7.2	12	120	5.0	0.42	0.08	53.	0.30	1.00	0.30	0.45
50769	500	5715	0	165	16	80	31	1.68	1.60	236	152	60	84	44	7.2	18	149	7.0	0.43	0.06	53.	0.30	1.00	0.30	0.45
51569	2220	14150	****	71	14	125	37	0.12	1.68	324	160	76	164	76	7.3	12	116	4.3	0.35	0.08	182.	0.35	2.00	0.18	0.60
51569	30	15100	****	47	25	62	39	0.14	1.78	312	200	108	112	4	7.3	21	157	6.5	0.35	0.05	182.	0.35	2.00	0.18	0.60
61269	305	33000	0	14000	8	33	13	0.35	0.28	136	68	28	68	16	7.7	2	52	2.1	0.75	0.36	68.	0.61	13.00	0.05	1.10
61769	1020	9000	4200	1250	23	107	42	0.31	0.87	348	172	124	176	72	7.2	7	117	5.3	0.42	0.08	70.	1.41	4.00	0.35	2.80
61769	1300	1250	750	750	11	77	17	0.16	1.54	292	204	124	88	60	7.6	13	108	8.0	0.45	0.06	70.	1.41	4.00	0.35	2.80
61769	1300	1500	1950	300	10	72	18	0.07	0.98	252	144	48	108	32	7.7	9	111	8.0	0.45	0.06	70.	1.41	4.00	0.35	2.80
62369	2245	8250	950	2750	14	83	27	0.12	1.20	364	128	76	236	40	7.6	12	94	2.8	0.83	0.30	153.	0.45	6.00	0.08	1.80
73169	750	2800	800	0	10	69	36	0.91	0.07	212	120	48	92	24	7.5	10	78	6.8	1.03	0.15	880.	0.08	1.00	0.08	0.10
81569	450	600	60	2900	10	72	***	0.18	0.44	400	124	60	276	76	7.4	2	60	2.8	0.35	0.13	17.	1.05	4.00	0.26	0.45
81569	720	0	17	2000	13	79	***	0.31	0.56	400	120	64	280	88	7.5	3	67	5.3	1.36	0.26	17.	1.05	4.00	0.26	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 9

DATE	TIME	BACTERIOLOGICAL NUMBER/ML T. COL.	F.COL.	F.STREP.	BOD	ORGANIC MG/L COD	TOC	NUTRIENT MG/L N	PO4	TOTAL	DS	SOLIDS MG/L VDS	SS	VSS	PH	OTHER MG/L CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
12969	1115	960	0	40	11	105	61	1.12	1.90	672	168	84	504	92	7.5	4	109	3.5	0.63	0.18	331.	0.45	4.75	0.10	0.20
22069	1535	361	0	0	9	120	36	1.30	1.15	460	192	112	268	28	7.2	7	162	8.6	0.68	0.08	135.	0.65	6.50	0.10	0.40
32369	840	260	0	0	4	64	22	1.19	1.25	280	140	80	140	40	7.4	4	93	11.2	1.25	0.11	718.	0.25	11.00	0.02	0.40
50769	200	10000	9	175	7	40	23	0.98	0.50	156	140	60	16	0	7.1	6	123	4.0	0.33	0.08	53.	0.30	1.00	0.30	0.45
50769	430	4000	0	25	7	40	23	0.98	0.50	156	140	60	16	0	7.1	6	123	6.5	0.43	0.07	53.	0.30	1.00	0.30	0.45
51569	2115	17000	****	30	***	***	***	*****	*****	****	****	****	****	****	****	***	***	3.3	0.80	0.24	15.	0.25	5.25	0.05	0.60
61269	400	75000	1000	11000	15	134	43	0.48	0.80	700	164	92	536	168	7.7	4	74	1.5	0.25	0.17	69.	0.60	12.00	0.05	1.10
61769	910	11000	1000	5750	13	90	30	0.22	0.87	360	68	36	292	80	7.5	4	76	1.9	0.35	0.18	72.	1.35	3.25	0.42	2.80
61769	1105	1000	1800	2250	12	119	54	0.36	1.12	788	236	184	552	316	7.8	3	76	3.8	0.40	0.11	72.	1.35	3.25	0.42	2.80
61769	1210	2750	2650	11000	11	73	28	0.03	1.02	320	204	116	116	60	7.6	7	140	4.9	0.45	0.09	72.	1.35	3.25	0.42	2.80
62369	2320	11250	0	2000	14	113	13	0.42	1.92	304	112	68	192	48	7.3	5	101	2.1	0.65	0.31	154.	0.45	4.50	0.10	1.80
73169	720	9300	50	1500	9	59	26	0.22	0.48	132	84	68	48	36	7.2	3	64	5.3	0.75	0.14	880.	0.20	1.25	0.16	0.10
81469	400	1600	440	50	***	261	***	0.53	0.69	576	272	208	304	80	7.1	7	125.	2.3	0.20	0.09	331.	0.75	4.75	0.16	0.25
81469	750	600	140	100	***	285	***	0.72	0.80	732	284	232	448	164	7.2	5	111	6.1	0.25	0.04	331.	0.75	4.75	0.16	0.25
81569	530	1100	60	3600	14	131	***	0.15	0.34	232	120	80	112	12	7.3	2	70	1.8	0.70	0.39	21.	0.25	5.00	0.05	0.45
81569	800	500	0	1300	8	69	***	0.13	0.64	404	124	84	280	16	7.5	1	52	4.3	1.90	0.44	21.	0.25	5.00	0.05	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 10

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L		TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND								
111068	1005	480	0	130	***	***	***	*****	*****	62	60	24	2	0	****	***	***	1.3	0.16	C.12	221.	0.45	5.00	0.09	1.05
111568	130	440	0	7C	13	140	27	1.12	2.00	204	88	56	116	44	7.4	***	***	5.0	0.46	0.10	4.	1.60	10.50	0.15	1.10
111568	145	720	0	90	15	140	29	1.12	2.00	180	96	22	84	58	6.7	***	***	5.3	0.56	C.11	4.	1.60	10.50	0.15	1.10
111568	200	3320	0	40	16	140	44	1.12	1.40	152	110	20	42	16	7.0	***	***	5.5	0.65	0.12	4.	1.60	10.50	0.15	1.10
111568	215	560	0	0	16	140	23	1.12	1.40	140	104	10	36	****	7.1	***	***	5.8	0.75	0.13	4.	1.60	10.50	0.15	1.10
111568	230	320	C	20	23	144	36	1.12	1.20	152	108	56	44	12	7.2	***	***	6.C	0.85	C.14	4.	1.60	1C.50	0.15	1.10
111568	245	400	0	50	20	144	26	1.12	1.20	150	116	48	34	16	7.0	***	***	6.3	0.95	0.15	4.	1.60	10.50	0.15	1.10
111568	300	280	0	30	10	***	28	*****	*****	164	112	28	52	24	7.0	***	***	6.5	1.05	C.16	4.	1.60	10.50	0.15	1.10
121868	1220	840	0	50	28	194	80	2.40	0.85	208	28	4	180	80	7.4	13	133	0.3	0.12	0.40	144.	0.60	1.00	0.60	0.30
121868	1235	240	0	0	26	286	***	2.40	0.85	****	****	****	****	****	****	***	***	0.6	0.14	C.23	144.	0.60	1.00	0.60	0.30
122768	20C	60	0	45	3	292	13	*****	*****	152	122	48	30	0	7.1	2	65	0.3	0.55	1.83	144.	0.12	1.00	0.12	0.50
122768	230	40	0	270	2	104	12	*****	*****	****	****	****	****	****	7.1	2	66	0.8	0.60	0.75	144.	0.12	1.00	0.12	0.50
122768	300	20	0	10	3	92	26	*****	*****	184	100	36	84	10	7.4	2	81	1.3	0.65	C.50	144.	0.12	1.00	0.12	0.50
122768	815	80	0	20	6	100	18	*****	*****	****	****	****	****	****	7.5	3	85	6.5	0.80	0.12	144.	0.12	1.00	0.12	0.50
122768	1100	40	0	5	6	104	20	*****	*****	230	142	68	88	10	7.3	9	122	9.3	0.84	0.09	144.	0.12	1.00	0.12	0.50
41769	130	285	1	200	8	76	43	2.38	1.20	968	64	24	904	104	7.3	3	78	3.3	0.93	0.28	67.	0.50	13.50	0.04	0.70
41769	230	570	0	115	7	64	97	2.31	1.00	808	48	40	760	88	7.3	3	76	4.3	1.03	C.24	67.	0.50	13.50	0.04	0.70
41769	330	270	1	67	7	56	53	2.24	0.90	800	100	40	700	80	7.3	3	76	5.3	1.05	0.20	67.	0.50	13.50	0.04	0.70
61269	515	38000	250	8250	5	36	15	0.11	0.30	264	224	140	40	12	7.5	10	104	2.8	0.28	C.10	69.	0.60	12.00	0.05	1.10
61769	920	250	300	0	7	64	19	0.12	0.46	332	120	48	212	32	7.6	3	61	2.1	0.36	C.17	72.	1.35	3.25	0.42	2.80
61769	1120	6750	200	1000	13	139	37	0.0	0.69	508	140	44	368	56	7.8	5	94	4.1	0.42	0.10	72.	1.35	3.25	0.42	2.80
62469	1015	4750	0	********	10	61	22	0.25	0.46	228	176	156	52	32	7.4	8	94	1.3	0.16	0.12	10.	0.65	1.75	0.37	2.40
62469	1105	4250	450	********	9	58	13	0.27	0.64	416	140	92	276	188	7.5	12	129	3.1	0.20	0.06	10.	0.65	1.75	0.37	2.40
62469	1145	8500	200	********	9	60	11	0.22	0.57	500	244	208	256	164	7.5	15	149	3.8	0.20	0.05	10.	0.65	1.75	0.37	2.40
73169	645	1500	0	4100	7	33	26	0.32	0.25	176	64	48	112	68	7.3	6	63	4.8	0.71	0.15	880.	0.20	1.25	0.16	0.10
73169	725	650	100	8400	6	52	***	0.38	0.28	410	184	124	226	20	7.4	14	105	5.4	0.75	C.14	880.	0.20	1.25	0.16	0.10
73169	805	1500	100	130	6	49	***	0.39	0.36	540	156	80	384	44	7.4	19	65	6.1	0.75	0.12	880.	0.20	1.25	0.16	0.10
81469	250	6000	40	100	17	174	***	0.31	0.42	454	280	204	174	88	7.1	21	163	1.1	0.20	0.18	331.	0.75	4.75	0.16	0.25
81469	530	1400	380	0	14	164	***	0.50	0.50	516	324	228	192	96	7.1	21	172	3.8	0.20	0.05	331.	0.75	4.75	0.16	0.25
81469	500	2600	20	0	11	138	***	0.51	0.52	468	256	160	212	88	7.3	21	166	7.3	0.25	C.03	331.	0.75	4.75	0.16	0.25
81569	600	200	340	1400	9	103	***	0.46	0.72	1180	88	52	1092	128	7.5	2	58	2.3	0.85	0.37	21.	0.25	5.00	0.05	0.45
81569	640	600	140	1000	7	69	***	0.27	0.62	1468	84	76	1384	92	7.5	2	52	2.9	1.18	0.41	21.	0.25	5.00	0.05	0.45
81569	1030	300	40	200	6	81	***	0.44	0.80	1376	128	64	1248	228	7.4	6	90	8.8	2.55	0.29	21.	0.25	5.00	C.05	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 11

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L					PH	OTHER MG/L	*	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS		CL	COND								
12969	1030	160	0	10	2	144	44	1.68	1.60	568	138	38	430	88	7.3	6	114	2.8	0.50	0.18	332.	0.45	4.75	0.10	0.20
12969	1100	240	0	0	3	144	75	2.10	1.70	672	114	14	558	144	7.4	4	109	3.3	0.55	0.17	332.	0.45	4.75	0.10	0.20
12969	1130	360	0	0	6	136	29	1.82	2.10	726	166	30	560	134	7.4	5	109	3.8	0.70	0.18	332.	0.45	4.75	0.10	0.20
12969	1200	440	0	30	6	103	50	1.40	1.90	547	180	94	367	24	7.6	5	103	4.3	0.85	0.20	332.	0.45	4.75	0.10	0.20
22069	1525	650	0	0	8	100	17	0.40	0.95	416	168	80	248	20	7.5	10	156	8.4	0.67	0.08	135.	0.65	6.50	0.10	0.40
32369	815	140	0	0	23	140	36	2.24	1.80	660	140	20	520	112	7.5	3	88	10.8	1.19	0.11	718.	0.25	11.00	0.02	0.40
32369	820	1750	0	0	13	64	27	1.05	1.10	358	128	32	230	100	7.4	4	102	10.8	1.20	0.11	718.	0.25	11.00	0.02	0.40
32369	1515	150	0	0	15	68	24	1.19	1.25	272	160	20	112	32	7.2	7	152	17.8	2.28	0.13	718.	0.25	11.00	0.02	0.40
50769	130	12000	4	50	12	80	25	1.87	0.60	320	208	40	112	52	7.1	12	175	3.5	0.26	0.07	53.	0.30	1.00	0.30	0.45
50769	400	6000	0	40	12	80	25	1.87	0.60	320	208	40	112	52	7.1	12	175	6.0	0.43	0.07	53.	0.30	1.00	0.30	0.45
50769	700	8000	0	5	12	80	25	1.87	0.60	320	208	40	112	52	7.1	12	175	9.0	0.43	0.05	53.	0.30	1.00	0.30	0.45
51569	2030	23750	****	125	8	102	37	0.20	1.24	772	276	156	496	80	7.3	8	169	2.5	0.78	0.31	692.	1.05	4.25	0.25	0.60
51569	2100	21100	****	65	12	82	39	0.19	1.06	516	204	164	312	56	7.4	7	135	3.0	0.80	0.27	692.	1.05	4.25	0.25	0.60
51569	2130	28100	****	5	10	89	28	0.23	0.88	464	180	108	284	76	7.4	5	118	3.5	0.80	0.23	692.	1.05	4.25	0.25	0.60
51569	2200	*******	****	*******	7	89	32	0.25	1.20	572	108	60	464	108	7.2	6	124	4.0	0.80	0.20	692.	1.05	4.25	0.25	0.60
61269	420	58000	500	11250	15	129	40	0.13	1.12	1016	168	120	848	128	7.9	4	78	1.8	0.26	0.14	69.	0.60	12.00	0.05	1.10
61769	500	12000	0	14000	21	202	55	0.22	1.63	680	232	48	448	216	7.7	5	111	1.8	0.35	0.20	72.	1.35	3.25	0.42	2.80
61769	1100	20000	0	3500	18	162	49	0.15	1.58	980	252	64	728	176	7.7	8	151	3.6	0.40	0.11	72.	1.35	3.25	0.42	2.80
61769	1240	4750	50	34500	16	138	6	0.19	0.95	760	320	172	440	148	7.5	8	153	5.4	0.45	0.08	72.	1.35	3.25	0.42	2.80
62369	2345	24000	2900	3500	13	85	26	0.34	1.53	608	180	88	428	44	7.7	3	87	2.5	0.65	0.26	154.	0.45	4.50	0.10	1.80
73169	710	9000	400	250	12	106	***	0.30	0.61	260	56	44	204	52	7.4	3	65	5.2	0.75	0.14	880.	0.20	1.25	0.16	0.10
81469	345	1100	60	450	24	215	***	0.42	0.86	596	396	272	200	160	7.1	6	113	2.0	0.20	0.10	331.	0.75	4.75	0.16	0.25
81469	445	800	40	100	22	179	***	0.33	0.71	544	264	264	280	172	7.0	6	114	3.0	0.20	0.07	331.	0.75	4.75	0.16	0.25
81469	645	400	0	100	22	179	***	0.30	0.70	476	204	104	272	84	7.0	6	115	5.0	0.25	0.05	331.	0.75	4.75	0.16	0.25
81569	520	700	260	2900	26	180	***	0.31	1.20	936	72	32	864	240	7.4	3	82	1.6	0.65	0.41	21.	0.25	5.00	0.05	0.45
81569	750	900	100	2300	16	81	***	0.17	0.76	496	112	48	384	100	7.5	1	52	4.1	1.81	0.44	21.	0.25	5.00	0.05	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 —Continued

TEST AREA NO. 12

DATE	TIME	BACTERIOLOGICAL NUMBER/ML T. COL.	F.COL.	F.STREP.	ORGANIC MG/L BOD	COD	TOC	NUTRIENT MG/L N	PO4	TOTAL	SOLIDS MG/L DS	VDS	SS	VSS	PH	OTHER MG/L CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
11569	1830	0	0	0	12	92	28	0.83	0.30	234	88	36	146	4	7.1	5	79	0.5	0.08	0.16	450.	1.24	22.00	0.06	0.30
11569	1850	0	0	0	11	40	17	0.60	0.30	162	86	42	76	3	7.1	4	83	0.8	0.10	0.13	450.	1.24	22.00	0.06	0.30
11569	1910	40	0	0	9	38	14	0.60	0.10	136	70	32	66	6	7.0	4	70	1.2	0.12	0.10	450.	1.24	22.00	0.06	0.30
11569	1930	120	0	50	8	36	18	0.60	0.20	****	****	****	****	****	7.0	4	53	1.5	0.13	0.09	450.	1.24	22.00	0.06	0.30
11569	1950	40	0	0	8	56	12	0.0	0.20	96	48	18	48	10	6.8	3	60	1.8	0.14	0.08	450.	1.24	22.00	0.06	0.30
11569	2010	40	0	0	8	76	11	0.0	0.20	****	****	****	****	****	6.8	4	62	2.2	0.15	0.07	450.	1.24	22.00	0.06	0.30
11569	2020	40	0	10	8	28	12	0.0	0.10	90	58	22	32	22	6.8	4	64	2.3	0.16	0.07	450.	1.24	22.00	0.06	0.30
12969	510	0	0	50	9	37	23	0.42	0.59	184	100	32	84	14	7.0	3	52	6.2	0.43	0.07	338.	0.45	7.00	0.06	0.20
12969	940	0	0	50	7	40	24	0.42	0.59	226	84	28	142	18	6.8	3	62	6.7	0.47	0.07	338.	0.45	7.00	0.06	0.20
12969	1010	80	0	10	8	33	27	0.21	0.50	244	88	42	156	14	6.8	3	61	7.2	0.51	0.07	338.	0.45	7.00	0.06	0.20
12969	1040	0	0	30	7	29	31	0.14	0.60	216	100	42	116	28	6.8	3	60	7.7	0.55	0.08	338.	0.45	7.00	0.06	0.20
22069	1200	875	0	10	23	107	62	1.33	0.50	168	80	32	88	16	7.4	5	110	4.0	0.70	0.18	148.	0.23	13.00	0.02	0.40
22069	1245	1500	0	12	13	53	41	1.19	0.30	148	100	44	48	36	7.0	5	93	4.8	0.70	0.15	148.	0.23	13.00	0.02	0.40
22069	1330	625	0	0	11	46	18	1.26	0.20	96	72	32	24	12	6.7	5	81	5.5	0.70	0.13	148.	0.23	13.00	0.02	0.40
32369	715	150	0	0	8	64	22	0.98	0.56	292	112	52	180	52	7.6	3	70	9.3	0.66	0.07	191.	0.08	6.00	0.01	0.40
50769	330	10000	5	15	9	28	24	1.12	0.50	72	56	16	16	8	7.1	2	51	5.5	0.43	0.08	53.	0.30	1.00	0.30	0.45
50769	600	8000	0	25	6	24	11	0.63	0.40	76	68	20	8	4	7.1	3	84	8.0	0.43	0.05	53.	0.30	1.00	0.30	0.45
51569	2245	11000	****	30	7	50	26	0.15	1.68	256	196	36	60	20	7.6	4	75	4.8	0.35	0.07	182.	0.35	2.00	0.18	0.60
51569	2400	7300	****	0	***	***	***	*****	*****	****	****	****	****	****	****	***	***	6.0	0.35	0.06	182.	0.35	2.00	0.18	0.60
61269	245	25000	0	5500	8	41	13	0.04	0.37	396	52	36	334	64	7.4	2	32	1.8	0.68	0.38	68.	0.61	13.00	0.05	1.10
61769	750	250	0	0	8	21	5	0.02	0.26	140	116	116	24	24	7.2	3	53	2.8	0.28	0.11	70.	1.41	4.00	0.35	2.80
61769	1000	250	100	250	6	32	21	0.0	0.37	132	124	68	8	8	7.4	3	72	5.0	0.41	0.08	70.	1.41	4.00	0.35	2.80
61769	1345	0	50	0	6	34	16	0.01	0.32	296	268	120	28	20	7.5	4	84	8.8	0.45	0.05	70.	1.41	4.00	0.35	2.80
62369	2230	4250	200	250	6	21	6	0.13	0.37	276	148	124	128	20	7.1	1	29	2.5	0.82	0.33	153.	0.45	6.00	0.08	1.80
73169	815	1300	0	0	8	45	***	0.16	0.66	96	88	80	8	8	6.9	3	55	7.3	1.03	0.14	880.	0.08	1.00	0.08	0.10
81469	730	50	0	0	8	47	***	0.12	0.70	148	148	104	0	0	6.9	3	68	2.5	0.60	0.24	334.	1.03	6.00	0.17	0.25
81569	430	1400	0	150	10	67	***	0.33	0.25	272	124	44	148	100	7.2	3	119	2.5	0.32	0.13	17.	1.05	4.00	0.26	0.45
81569	820	0	0	250	3	47	***	0.12	0.27	136	104	84	32	0	7.2	1	32	6.3	1.99	0.32	17.	1.05	4.00	0.26	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 13

DATE	TIME	BACTERIOLOGICAL NUMBER/ML T. COL.	F.COL.	F.STREP.	ORGANIC MG/L BOD	COD	TOC	NUTRIENT MG/L N	PO4	SOLIDS MG/L TOTAL	DS	VDS	SS	VSS	PH	OTHER MG/L CL	* COND	TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
100968	640	101	****	200	6	***	***	*****	*****	248	72	16	176	64	7.2	71	***	2.4	0.53	0.22	88.	1.07	5.25	0.20	1.30
100968	655	50	****	220	6	***	***	*****	*****	256	32	16	224	80	7.2	71	***	2.7	0.58	0.21	88.	1.07	5.25	0.20	1.30
100968	710	33	****	181	4	***	***	*****	*****	288	40	20	248	48	7.2	71	***	2.5	0.60	0.21	88.	1.07	5.25	0.20	1.30
101668	1825	********	****	7	14	***	***	*****	*****	****	****	****	****	****	7.5	7	***	4.2	0.32	0.08	176.	0.60	2.25	0.27	1.10
101668	1840	********	****	3	9	***	***	*****	*****	192	52	44	140	0	7.6	7	***	4.4	0.33	0.08	176.	0.60	2.25	0.27	1.10
101668	1855	********	****	0	9	***	***	*****	*****	184	86	58	98	6	7.5	7	***	4.7	0.35	0.07	176.	0.60	2.25	0.27	1.10
101668	1910	********	****	1	7	***	***	*****	*****	148	64	14	84	18	7.2	7	***	4.9	0.35	0.07	176.	0.60	2.25	0.27	1.10
101668	1925	********	****	1	***	***	***	*****	*****	126	98	60	28	****	****	***	***	5.2	0.35	0.07	176.	0.60	2.25	0.27	1.10
110268	1245	********	160	460	22	***	***	*****	*****	352	112	44	240	30	7.0	7	***	4.3	0.80	0.19	350.	0.35	4.00	0.09	0.35
110268	1630	********	80	120	10	***	***	*****	*****	302	172	52	130	22	7.1	10	***	2.3	1.10	0.48	350.	0.35	4.00	0.09	0.35
41369	600	10	0	7	0	16	12	0.42	0.0	324	312	112	12	4	8.0	28	261	2.5	0.12	0.05	466.	2.65	21.00	0.13	0.40
41369	700	0	0	0	0	12	28	0.56	0.10	320	320	136	0	0	8.0	28	263	3.5	0.14	0.04	466.	2.65	21.00	0.13	0.40
41369	800	0	0	11	0	12	11	0.98	0.20	344	340	160	4	0	8.1	28	263	4.5	0.18	0.04	466.	2.65	21.00	0.13	0.40
41769	245	510	9	87	34	172	61	3.50	2.30	488	120	64	368	80	7.0	3	72	4.8	0.90	0.19	82.	0.35	8.50	0.04	0.70
41769	345	240	4	103	32	132	51	3.50	1.90	440	120	40	320	80	7.0	4	99	5.8	0.90	0.16	82.	0.35	8.50	0.04	0.70
41769	445	430	0	323	13	104	33	3.43	1.70	300	80	20	220	48	7.0	5	109	6.8	0.90	0.13	82.	0.35	8.50	0.04	0.70
42669	1900	********	****	********	43	264	65	6.44	2.40	768	160	96	608	168	7.1	25	181	0.0	0.0	0.0	119.	0.15	1.50	0.11	0.65
42669	1920	********	****	********	43	280	71	6.37	2.20	744	208	116	536	164	7.0	31	204	0.3	0.01	0.03	119.	0.15	1.50	0.11	0.65
42669	1940	********	****	********	43	248	75	5.39	1.90	522	150	72	372	108	6.9	20	172	0.7	0.05	0.07	119.	0.15	1.50	0.11	0.65
42669	2000	********	****	********	34	208	78	4.90	1.80	232	112	48	120	60	6.9	13	135	1.0	0.12	0.12	119.	0.15	1.50	0.11	0.65
42669	2020	********	****	********	35	172	52	4.62	1.70	472	184	64	288	88	6.8	9	116	1.3	0.15	0.11	119.	0.15	1.50	0.11	0.65
42669	2040	********	****	********	34	148	56	4.20	1.40	328	168	96	160	56	6.8	9	121	1.7	0.15	0.09	119.	0.15	1.50	0.11	0.65
61469	745	********	100	0	5	46	19	0.38	1.92	2304	176	124	2128	288	7.2	2	69	3.5	1.10	0.31	25.	0.55	1.50	0.42	2.25
61469	845	********	200	0	4	47	14	0.29	1.72	720	140	56	580	116	7.2	2	60	4.5	1.19	0.26	25.	0.55	1.50	0.42	2.25
61469	945	********	200	0	4	47	18	0.23	1.72	884	100	20	784	716	7.2	2	60	5.5	1.20	0.22	25.	0.55	1.50	0.42	2.25
62469	1040	17000	1100	1750	7	73	28	0.16	0.92	208	112	104	128	80	7.3	3	59	5.7	0.32	0.06	6.	0.75	2.00	0.38	2.40
73169	510	1500	0	500	7	48	33	0.18	0.60	300	124	108	176	40	7.2	2	49	2.4	0.41	0.17	880.	0.35	5.75	0.06	0.10
81569	650	100	20	2700	7	61	***	0.16	0.70	444	124	80	320	52	7.0	2	56	2.8	0.85	0.30	20.	0.15	1.50	0.10	0.45
81569	900	300	300	4300	5	93	***	0.14	1.26	1240	144	80	1096	92	7.3	1	46	5.0	1.90	0.38	20.	0.15	1.50	0.10	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 14

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L					OTHER MG/L			TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND								
111568	350	6000	27	190	11	36	31	1.68	2.20	424	400	192	24	10	6.9	***	***	3.8	0.68	0.18	104.	0.50	6.30	0.08	1.10
111568	405	7040	14	120	22	56	37	1.68	2.20	640	278	56	362	88	6.7	***	***	4.1	0.71	0.17	104.	0.50	6.30	0.06	1.10
111568	420	7200	0	170	26	56	49	2.66	2.65	816	290	84	526	100	6.7	***	***	4.3	0.75	0.17	104.	0.50	6.30	0.08	1.10
111568	435	6880	27	210	29	48	41	2.66	2.65	814	272	32	542	152	6.7	***	***	4.6	0.79	0.17	104.	0.50	6.30	0.08	1.10
111568	450	4000	0	170	29	40	36	1.96	2.65	646	182	46	464	36	6.7	***	***	4.8	0.83	0.17	104.	0.50	6.30	0.08	1.10
111568	505	6400	0	140	26	36	33	1.96	2.65	450	160	40	290	30	6.7	***	***	5.1	0.86	0.17	104.	0.50	6.30	0.08	1.10
111568	520	5600	0	150	15	48	23	1.40	2.65	384	192	138	192	178	6.8	***	***	5.3	0.90	0.17	104.	0.50	6.30	0.08	1.10
122768	215	40	0	50	6	68	29	2.80	0.20	608	198	36	410	72	****	18	154	0.3	0.35	1.17	144.	0.12	1.00	0.12	0.50
122768	230	80	0	10	7	68	47	2.80	0.20	****	****	****	****	****	7.2	19	148	0.5	0.40	0.80	144.	0.12	1.00	0.12	0.50
122768	245	40	0	15	6	84	43	2.80	0.0	752	262	72	490	78	7.2	32	178	0.8	0.45	0.56	144.	0.12	1.00	0.12	0.50
122768	300	80	0	10	5	84	41	2.80	0.0	776	256	40	520	72	7.5	31	190	1.0	0.50	0.50	144.	0.12	1.00	0.12	0.50
122768	315	120	0	10	6	80	34	2.50	0.0	****	****	****	****	****	7.2	29	182	1.3	0.53	0.41	144.	0.12	1.00	0.12	0.50
122768	330	40	0	0	5	80	36	2.50	0.0	****	****	****	****	****	7.2	27	167	1.5	0.55	0.37	144.	0.12	1.00	0.12	0.50
122768	345	60	0	0	4	64	19	2.50	0.20	188	86	64	102	****	7.2	21	157	1.8	0.58	0.32	144.	0.12	1.00	0.12	0.50
122768	530	80	0	0	7	52	24	2.50	0.10	413	206	78	207	15	7.4	18	149	7.5	0.75	0.10	144.	0.12	1.00	0.12	0.50
61469	710	*******	700	750	8	74	28	0.82	2.25	916	128	44	788	92	7.0	8	88	2.9	0.98	0.34	25.	0.55	1.50	0.42	2.25
62469	1050	14250	950	250	9	51	18	0.36	0.87	1068	212	72	856	828	7.5	17	163	5.8	0.33	0.06	6.	0.75	2.00	0.38	2.40
81569	850	0	0	1000	6	22	***	0.13	0.27	48	28	28	20	20	7.1	1	38	4.8	1.79	0.37	20.	0.15	1.50	0.10	0.45

* MICROMHOS/CM

**** NO DATA

TABLE M-2 — Continued

TEST AREA NO. 15

DATE	TIME	BACTERIOLOGICAL NUMBER/ML			ORGANIC MG/L			NUTRIENT MG/L		SOLIDS MG/L						OTHER MG/L			TIME SINCE START (HRS)	ANT. AMOUNT (IN.)	ANT. AVERAGE INTENSITY (IN./HR.)	TIME SINCE ANT. EVENT (HRS.)	AMOUNT OF ANT EVENT (IN.)	DURATION OF ANT. EVENT (HRS.)	AVERAGE INTENSITY ANT. EVENT (IN./HR.)	API
		T. COL.	F.COL.	F.STREP.	BOD	COD	TOC	N	PO4	TOTAL	DS	VDS	SS	VSS	PH	CL	* COND									
110268	1230	********	80	40	19	***	***	*****	*****	180	64	28	116	32	6.7	3	***	4.0	0.70	0.18	350.	0.35	4.00	0.09	0.35
110268	1300	********	80	40	10	***	***	*****	*****	90	30	12	60	22	6.7	3	***	4.5	0.90	0.20	350.	0.35	4.00	0.09	0.35
110268	1330	********	40	0	10	***	***	*****	*****	104	60	28	44	36	6.7	3	***	5.0	0.93	0.19	350.	0.35	4.00	0.09	0.35
110268	1400	********	60	20	11	***	***	*****	*****	88	66	30	22	12	6.7	3	***	5.5	0.95	0.17	350.	0.35	4.00	0.09	0.35
110268	1430	********	40	20	11	***	***	*****	*****	78	54	20	24	20	6.7	3	***	6.0	0.98	0.16	350.	0.35	4.00	0.09	0.35
110268	1500	********	60	0	7	***	***	*****	*****	****	62	40	****	****	6.7	3	***	6.5	1.00	0.15	350.	0.35	4.00	0.09	0.35
110268	1530	********	220	0	6	***	***	*****	*****	64	36	22	28	10	6.7	3	***	7.0	1.03	0.15	350.	0.35	4.00	0.09	0.35
111068	1015	1280	20	150	***	***	***	*****	*****	****	****	****	****	****	****	***	***	0.8	0.08	0.10	350.	0.35	4.00	0.09	1.05
111568	130	1240	20	150	17	64	24	1.54	4.30	204	188	150	16	0	6.7	***	***	1.5	0.08	0.05	104.	0.50	6.25	0.08	1.10
111568	145	2720	100	100	34	64	28	1.54	4.30	142	138	6	4	0	6.7	***	***	1.8	0.11	0.06	104.	0.50	6.25	0.08	1.10
111568	200	4400	27	140	41	60	38	0.70	2.50	****	104	66	****	****	6.6	***	***	2.0	0.15	0.08	104.	0.50	6.25	0.08	1.10
111568	215	5200	47	150	31	60	38	0.70	2.50	86	66	60	20	10	6.4	***	***	2.3	0.25	0.11	104.	0.50	6.25	0.08	1.10
111568	230	2720	21	140	16	40	44	0.56	1.40	68	****	****	****	****	6.4	***	***	2.5	0.35	0.14	104.	0.50	6.25	0.08	1.10
111568	245	2720	7	110	15	40	35	0.56	1.40	74	52	40	22	18	6.6	***	***	2.6	0.45	0.16	104.	0.50	6.25	0.08	1.10
111568	300	2720	0	140	16	40	22	0.56	1.40	****	66	62	****	****	6.6	***	***	3.0	0.55	0.18	104.	0.50	6.25	0.08	1.10
122768	230	440	0	0	26	36	81	1.40	0.60	196	86	44	110	38	6.9	3	***	0.5	0.25	0.50	144.	0.12	1.00	0.12	0.50
122768	500	2960	0	0	4	44	68	0.56	0.10	80	68	42	12	****	6.9	2	45	1.3	0.75	0.58	144.	0.12	1.00	0.12	0.50
61469	730	********	300	500	1	18	11	0.16	0.71	700	20	8	680	624	7.0	1	30	3.3	1.05	0.32	25.	0.55	1.50	0.42	2.25
62469	1030	14500	1350	500	10	62	18	0.15	0.98	396	172	88	224	56	7.0	3	50	5.5	0.30	0.05	6.	0.75	2.00	0.38	2.40
73169	500	5000	0	2400	14	54	23	0.22	1.07	160	88	62	72	24	6.8	2	41	2.3	0.40	0.17	880.	0.35	5.75	0.06	0.10
81569	705	200	0	2500	13	71	***	0.31	0.64	280	132	112	148	84	6.7	1	41	3.1	0.93	0.30	20.	0.15	1.50	0.10	0.45
81569	910	200	0	2800	6	40	***	0.20	0.58	364	124	100	240	104	6.8	1	29	5.2	1.93	0.37	20.	0.15	1.50	0.10	0.45

* MICROMHOS/CM

**** NO DATA

APPENDIX N

GENERAL PLAN FOR THE CITY OF TULSA TO CONTROL STORM WATER POLLUTION

Introduction

From the onset of this project, it was visualized that, because of the amounts of pollution found in urban surface drainage in the Tulsa Metropolitan Area, remedial measures would relate to institutional and regulative actions rather than extensive structural facilities. It must be remembered that a single method of control or treatment would usually not be sufficient to cope with all sources of storm water pollution in an urban area. The varying surface characteristics, including land use in an urban community, demand, under specific circumstances, those methods which are the most feasible for each specific subdrainage basin. The analysis must take into account the sewer hydraulics, topography, land use, availability of construction sites, rainfall and runoff characteristics, water quality standards for the receiving waters, and many other factors.

In the Tulsa Metropolitan Area, the basic plan of action should emphasize institutional and regulatory measures which are necessary for a completely integrated storm water pollution control program. In the future, it is quite possible that physical approaches may have to be utilized at several points in the storm water system to completely alleviate the problem. The three basic physical methods are: (1) control--includes storm water system regulators, retention basins, etc.; (2) treatment--includes microstraining, high rate filtration, chlorination, dissolved air flotation, etc. ; and (3) a combination of the two.

It is quite apparent that, as state standards relating to water pollution are established, local governments will be responsible for upgrading or maintaining the quality of interstate and intrastate waters. Local jurisdictions will find it necessary to adopt local standards to control all sources of pollution. In order to avoid the possibility of forfeiting the right to control these sources of pollution, including storm water pollution, local communities should begin to develop sound water pollution control regulations to prevent all unnecessary contaminants from entering their waterways.

Development of appropriate plans of action at an early date would prevent further degradation of the receiving streams in the Tulsa area.

Preventing and abating storm water pollution is a costly and complex problem. The economic benefits to be gained are not readily apparent and are often long range in nature. Strong prevention-type programs are the most economical. Prevention as used in this context refers to institutional and regulatory programs to reduce the amount of contaminants reaching the drainage channels and to utilize depletion methods which reduce the amount of runoff.

The plan presented in this section is specifically related to the Tulsa urban area. It may be adopted for use in other areas if demonstrated feasible. The course of action is presented as a list of recommendations for consideration by the various public agencies and policymakers. Preceding these recommendations are several facts concerning storm water pollution in Tulsa.

Storm Water Pollution Facts

1. The average daily BOD population equivalent (0.17 lbs. BOD/day/person) of storm water runoff in Tulsa is over 26,000.

2. The average daily storm water pollution percentage contributions of total pollutional load (storm water runoff plus municipal effluents) are:

Pollutional Parameter	Percentage
BOD	20
COD	30
Suspended solids	85
Organic Kjeldahl nitrogen	30
Soluble orthophosphate	4

   It should be noted that, as improved sanitary treatment facilities are provided in the Tulsa area, the primary source of pollutional loads to the receiving streams will be storm water runoff.

3. Approximately 52 rainfall events occur per year, causing a storm water BOD load to the receiving streams of 160% of the average daily BOD sanitary treatment plant effluent loads. This "shock" load normally occurs in less than a two hour period.

4. The continued urbanization of the Tulsa area will cause an increase in the volume of storm water runoff with its associated pollutional

loads into the Arkansas River and Bird Creek, the major receiving streams in the area. Of the two, the greater problem exists on Bird Creek. At present, only about a third of the daily flows within the creek are greater than the volumes of effluent discharged from the metropolitan sewage treatment plants within the basin. By 1990, the daily flows within the creek will be exceeded 76% of the time by the daily volume of sewage effluent. The construction of a proposed dam in the upper Bird watershed should increase the amount of flow within the creek and provide a greater degree of dilution. Such a dam, however, would not alleviate the problem caused by storm water runoff.

With more complete urbanization in the Tulsa portion of the basin, shock loads of pollution from storm events will be added in larger amounts and with greater frequency to the lower reaches of Bird Creek. Consequently, the environs in the lower reaches of Bird Creek will probably continue to remain in a poor ecological state.

5. The storm water additions to the Arkansas River should cause no problems in the foreseeable future as long as the river remains in its present state and no extreme condition develops which drastically increases the amounts of pollution entrained in storm flows. If, however, the River Lakes plan is implemented, the problems of storm water pollution will have to be examined more critically, as illustrated in Section 9 of this report.

   After the first of the three dams of the River Lakes plan is constructed, an extensive program of sampling and evaluation should be initiated, and corrective actions taken to lessen the impact of storm water pollution.

Recommended Actions

1. Several methods for determining the amounts of pollution generated on urban watersheds are presented elsewhere in this report.

   > It is recommended that one of these methods be adopted. This would allow planners to make comparisons as to the runoff- and pollution-producing capabilities from storm events during the transition from a natural to an urbanized watershed. These comparisons could be made for various plans of land use and schedules of development.

2. The study established the influential role that an impervious area within a watershed exerts on the runoff regimen. Complete listings of impervious area for each parcel in the Land Use Activity File are not available.

   It is recommended that information on streets, drives, parking areas, roofs, and other man-made imperviousness be maintained for each parcel. This information would not only be helpful in determining the amount of storm water pollution which could be expected from the parcel, but would aid in the determination of peak rates of flow for the design of culverts and floodways required to pass the flows. This information could be used by the street department to plan sweeping schedules and to estimate the effort required in snow removal or sanding operations. Other uses of this data could include parking surveys, estimations of the cost for area renewal, and evaluation of the trends of land use.

3. In any new program of water pollution control, it is necessary to have an organization to review the nature and extent of the problem and to establish the guidelines under which the program can best be financed, administered, and implemented.

   It is recommended that the elected officials of the City of Tulsa appoint a Storm Water Pollution Control Advisory Council. This advisory council should be made up of individuals from the Tulsa Metropolitan Area Planning Commission, Indian Nations Council of Governments, City Engineering Department, County Engineering Department, Tulsa City-County Health Department, local U. S. Soil Conservation Service, Corps of Engineers, City of Tulsa Water and Sewer Department, State Water Pollution Control Board, and Tulsa Home Builders Association.

4. One of the major water pollution problems of urban areas was visually observed throughout the project period. This problem is that of silt and debris which washes into the storm drainage channels and streams when natural cover is stripped from the ground in preparation for construction. These source areas include housing subdivision developments, expressway construction, renewal projects, and many others.

   For example, in new subdivision developments and urban renewal areas, the ground cover is usually removed for the purpose of laying sewer and storm water lines, constructing streets, and grading building sites. After the cover is removed, the topsoils are exposed, offering the potential of erosion by storm water runoff. If precipitation occurs during the time the soil is exposed, the runoff erodes and carries the loose soil into the drainage system, thus causing a high suspended solids concentration. The effects of this pollution are: (1) clogging of inlets, (2) filling of catch basins, (3) reduction of the capacity of the drainage structures, and (4) blockage and thus retention of storm water contaminants. This type of pollution should be regulated at its source by establishing specific regulations for builders, contractors, and developers. A model program would be one that would require the builders and developers to refrain from clearing the land until it was absolutely necessary for a particular phase of construction.

> It is recommended that regulations be adopted by the City and County Commission which would prevent and control this type of water pollution. For example, specific items of erosion control should be incorporated into the TMAPC's subdivision regulations and also should be included in expressway contracts. Specific community action guidelines for soil erosion and sediment control have been published by the National Association of Counties Research Foundation (22). The guidebook presents the legal authority, planning, personnel, and financing aspects of soil erosion and sediment control. The material included in the manual describes a model approach which, with appropriate modifications, should be used by the City of Tulsa and Tulsa County to control the solids pollutional load to the receiving streams. Many aspects of the guidebook could be used for developing a complete storm water pollutional control program.

In addition, on-site inspections of development and construction activities must be provided for assurance of compliance with the approved plans. These inspections should be housed in the Protective Inspections Office of the City of Tulsa and in the County Engineering Office. Permanent sediment control measures should be made a part of the general maintenance operations of the local government. In Tulsa these measures should be programmed as part of the Storm Sewer Section of the City Engineer's Office. In the county, these inspections should be accomplished by the County Engineering Office.

5. Economical incorporation of storm water pollution control measures, especially soil erosion and control measures, can only be accomplished in newly developing drainage sheds where no storm drainage structures have been built or in urban renewal areas where existing systems can be replaced. In the Tulsa Metropolitan Area, the most logical places to start on such programs are within newly developing basins.

It is recommended that the Tulsa Metropolitan Area embark upon a program of incorporating storm water depletion and control methods in all newly developing drainage basins and urban renewal areas. Also, as economic feasibility permits, control measures should be included into the open space and parks program. Storm water depletion and control concepts should be incorporated in several planned projects in the Tulsa area. These projects are: (1) the Flat Rock Creek Flood Plain Open Space Project, (2) the lower Joe Creek Flood Prevention Project, and (3) urban renewal projects in the Model Cities and West Bank areas.

The Tulsa Urban Renewal Authority should include storm water pollution control measures as part of all its projects. In the future, all Federally assisted projects may require this type of control. Possible areas of demonstration are: (1) rooftop or underground storage of storm water with reuse of the captured water for lawn irrigation or other non-potable uses, (2) small reservoirs for upstream retention and treatment in blue-green recreational areas, and (3) underground holding tanks for roof and parking areas.

6. After the alternatives for urban development within a watershed have been established, appropriate strategies for controlling and depleting storm water to minimize the pollutant load should be structured. The evaluation of a workable plan for storm water pollution abatement prior to development is the most economical and desirable approach for a community. Coordination between the planning and action agencies of the municipality and between private interests is desired during the early phases of planning.

It is recommended that practices, either as agency operating procedures or ordinances, be adopted to establish the responsibilities of the public agencies and the landowners within each basin in order to effect the utmost cooperation. The most important factor for consideration is that of cost. Some system for the apportionment of costs for easements, construction, and maintenance of the watershed drainage system must be developed in accordance with the production and rate of runoff and pollutants from the individual parcels. For example, property owners within a hillside development could be assessed a charge based on the runoff from the impervious portions of their lots, the runoff from roads and streets which connect their properties to the regional network of highways, and the sediment hazard during construction and development of the subdivision. Some other items to be considered in the establishment of ordinances and standard operating procedures are: the land uses to be allowed within the drainageway and the method of policing these uses; the responsibility for the maintenance of the drainage channel, channel banks, and flood plains; and the responsibility for a continuing evaluation of drainage system development within the site and the effect of this development on the regional system.

7. Numerous source areas of storm water pollution were found to be located on commercial and industrial land. Many types of contaminants come into contact with storm water as it flows across land parcels where raw and waste materials are stored in the open and are unprotected from the elements. Open drainage channels frequently run across the property where these sources are located, and in some situations the channel is used as a "sink" for disposing solid and liquid waste materials. These findings were supported by the analytical observations from several test areas, complaints received by the City Engineer and Health Department, and on-site inspections.

   It is recommended that a Commercial and Industrial Storm Water Pollution Control Ordinance be prepared by an advisory council and adopted by the City and County Commissions. This ordinance should include a strong enforcement section.

8. The impervious areas of an urban community are the greatest sources of storm water pollution. The primary source areas are the streets. Secondary sources are large parking areas, sidewalks, and roofs. Abating the contaminants at these sources is essential for any degree of storm water pollution control.

   It is recommended that programs be developed to increase the "cleanliness" of these source areas. The street cleaning effort should be increased. Performance standards of cleanliness should be developed, adopted, and enforced for commercial and industrial areas.

9. Depressions in the drainage channels, as well as on the land parcels, hold runoff water, thus allowing time for organic matter to decompose. Because of the flushing action of runoff water, substantial amounts of pollution are added to the receiving streams.

   It is recommended that these depressions in the drainage channels and conduits (both natural and enclosed) be eliminated by a planned program of improvement.

   A possible approach would be that Model Cities incorporate a storm drainage system cleanup and maintenance project in their program. The work crews should be recruited from the Model City Area in order to provide summer jobs for high school students in the area and to accomplish an even greater need--that of public awareness.

10. Tulsa is creating a model approach to the flood-control and parks programs. This approach involves the creation of parks for public use in the flood-plain zone of the remaining natural streams adjacent to the urban area. The plan is intended to accomplish two things: (1) to prevent flood damage to the public sector by not allowing residential and commercial development in the flood-plain area, and (2) to preserve natural resources and to create recreational areas.

    It is recommended that upstream control techniques be included as part of the overall plan. Procedures and techniques utilized by agricultural interests to reduce erosion and runoff from crop land can be adapted for use in the upstream areas. The capture and storage of storm water for reuse is a concept for control of storm water pollution that offers the most tangible benefits. Runoff is collected and diverted to storage basins dispersed throughout the urban area. Possible uses of the captured runoff are: (1) specialized industrial uses, (2) crop and lawn irrigation, (3) recreational lakes and ponds, (4) ground water recharge, and (5) non-potable domestic uses. The benefits derived from the use of storm water can be used to offset the cost of the storage and collection system.

    Upstream control techniques would not only deplete the urban runoff but possibly would offer some degree of treatment before the water was released to the receiving streams. If upstream control programs are not included in the overall plan, the recreational areas located in the flood plains downstream could become contaminated with pollutants from the urban areas upstream. Including storm water control measures would increase the benefits of the multi-purpose plan and demonstrate the program's feasibility, thereby encouraging its use in other municipalities. It is further recommended that concepts for depletion and/or treatment of storm water be considered in approving new development in the Mingo and Haikey Creek Watersheds.

11. General "housekeeping" practices on commercial and industrial lands need to be improved. The open storage of solid and liquid wastes on these properties constitutes an important source of storm water pollution.

    It is recommended that proper ordinances and regulations be adopted to regulate potential sources of pollution caused by the present general storage practices for waste material and/or raw material.

12. Contractors and builders dispose of their waste materials and rubbish in the nearest depression, which, more times than not, is the nearest drainage channel. Some of this material becomes entrained as either suspended or dissolved solids in storm flows.

    It is recommended that drainage channels be kept clear of building debris. This is especially important at inlets or outlets to closed drainage systems.

13. Possible storm water treatment techniques applicable to completely developed urban areas which already have a substantial investment in a storm drainage system need to be investigated. Several methods involving gas transfer processes show promise. One is the direct transfer of high purity oxygen to the receiving streams and/or small metropolitan reservoirs to improve the assimilative capacity and quality of streams and impoundments. Alternate methods would be induced aeration using surface mechanical aerators and diffusion (bubble) aeration or natural stream aeration through construction of static devices in the stream channel area.

    It is recommended that consideration be given for conversion of the Flat Rock Creek and Coal Creek sanitary sewage treatment plants into storm water treatment facilities after the facilities are phased out and the sanitary flow diverted to the North Side Plant. The plants could be converted into high rate plastic media trickling filters, high rate sand filters, dissolved air flotation units, or rotating filter units for treating the "first flush" of storm water runoff. After completing this task, the units could treat the partial flow for the remainder of the storm. In addition, either chlorination or ozonization could be provided to enhance the bacterial quality of the plant effluent.

14. Because the general public as well as the commercial and industrial sectors cause urban pollution, it is imperative that they become involved in the remedial processes for abating urban storm water pollution.

    It is recommended that an extensive public awareness program be initiated to inform the public of the problems and corrective measures necessary to abate the sources of urban storm water pollution. This should be done on the local level since this level is closest to the problem. Possible instigators of such programs are the Tulsa Metropolitan Area Planning Commission, the Tulsa City-County Health Department, the City Street Department, and the City Engineer's Office.

15. It is quite obvious that the cost involved in reducing or treating storm water pollution from urban runoff will be very high in most instances. Therefore, the most economical solution may be techniques involving control and treatment before the contaminants are discharged directly into receiving waters.

    It is recommended that planners and engineers of separate storm water systems minimize the number of outfalls within the limits of feasibility and practicality in order to reduce the number of points of control, should such action be necessary. For example, there are approximately 100 points with storm water outfalls along the east bank of the Arkansas River from the Sand Springs Bridge southward to 56th Street.

Proposed Storm Water Demonstration Projects

The storm and combined sewer pollution control branch of the Federal Water Quality Administration has listed pertinent areas of interest for research and development. In line with these research needs, problems relevant to interest areas of local municipal agencies are presented in this section. It is felt that these problems are important in the Tulsa area and that they are worthy of further consideration as demonstration projects by the agencies listed.

A. Tulsa Urban Renewal Authority

West Bank Project

1. Capture storm water runoff in a reservoir system for:
    a. possible reuse by DX, Texaco, or Public Service Company.
    b. possible treatment by one of the refineries.

2. Demonstrate parcel storm water control techniques in commercial or apartment areas by:
    a. rooftop storage.
    b. holding tanks for roof and parking areas.
    c. small open reservoirs for upstream control in blue-green areas.

B. Park Department and City Engineer's Office

Flat Rock Multi-Purpose Park and Storm Water Project

1. Plan storm water retention concepts in conjunction with parks and demonstrate two debris control methods:
    a. intensified street cleaning, general sanitary parcel cleanliness, and drainage channel maintenance.
    b. capture of debris at reservoir site by use of units which utilize microstraining, rotating filters, cyclones, or dissolved air flotation.

2. Demonstrate use of new material and/or construction methods of storm drains in Sunny Slope Addition (this addition has no storm drains), or demonstrate an off-system storage concept.

3. Demonstrate storm water rooftop collection and storage in public buildings such as fire stations, public schools, or sewage treatment plants. Costs and feasibility of utilizing the captured runoff for non-potable uses can be

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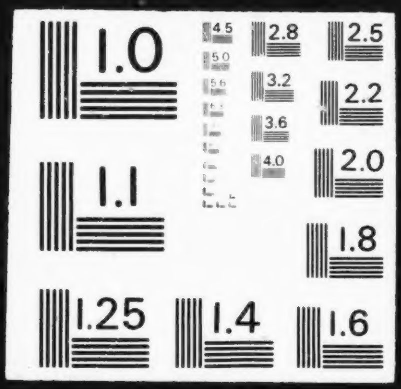
1.0
4.5
2.8
2.5
5.0
5.6
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

determined in conjunction with the storage and collection concepts.

4. Demonstrate in-line aeration or chlorination systems for use in existing storm sewers.

C. TMAPC

Subdivision Regulations and Zoning

1. Develop extensive storm water quantity and quality regulations for builders, contractors, and land developers.

2. Put together demonstration project which evaluates the effectiveness of the new regulations. Expertise of other action agencies of the city can be utilized in this phase.

D. Tulsa City-County Health Department

1. Develop commercial and industrial land "housekeeping" regulations and enforcement procedures for open storage of raw, finished, and waste products.

2. Evaluate the effectiveness of existing urban storm water catchments and impoundments.

In addition, the Federal Water Quality Administration is very interested in other storm and combined sewer demonstration projects. Problems associated with "marginal" pollution, such as uncontrolled dispersed loads from urban storm water runoff, can only increase as the percent of total discharged municipal and industrial waste loads increases. These sources must be recognized now and planning initiated to improve the system efficiencies in order to bring storm water flows under control.

Areas of other needed demonstration projects that have applications in the Tulsa urban area are:

1. Improved catch basin design.

2. Use of new sewer (both sanitary and storm) sealants.

3. Sewer flushing solids control.

4. Sequential screening of storm water.

5. Completely integrated control and treatment systems in moderate-sized urbanizing drainage basin.

6. Effects of street cleaning on quality of urban runoff.

7. Demonstration of "flow-thru" storm water treatment facility.

8. Use of seepage basin for treating runoff from the expressway system--especially at large interchanges.

9. Assessment of techniques of urban land use modifications and their application to control of urban runoff.

BIBLIOGRAPHIC: Avco Economic Systems Corporation,
Storm Water Pollution from Urban Land Activity,
FWQA Publication No. 11034FKL07/70, 1970.

ABSTRACT: An investigation of the pollution concentrations and loads from storm water runoff in an urban area was conducted in Tulsa, Oklahoma. The scope of the project included: a field assessment of the storm water pollution by obtaining samples of the water resulting from precipitation and surface runoff from selected test areas within the metropolitan area; development of an analytical procedure for correlation of storm water pollution with selectively defined variables of land uses, environmental conditions, drainage characteristics, and precipitation; and development of a plan for implementing remedial measures necessary to abate or control sources of pollution in an urban area.

Storm water runoff samples were collected from 15 "discrete" test areas in the Tulsa metropolitan area for laboratory analysis in terms of quality standards for BOD, COD, TOC, organic Kjeldahl nitrogen, soluble orthophosphate, chloride, pH, solids, total coliform, fecal coliform, and fecal streptococcus pollutants.

Selected land use parameters, environmental conditions, drainage and precipitation data, along with storm water pollution factors provided input data for functional relationships to enable assessment of pollution from storm water runoff.

Recommendations were made for a plan of action for preventing and controlling storm water pollution from urban areas.

ACCESSION NO:

KEY WORDS:
Storm Water Pollutio
Urban Runoff
Land Use Indicators

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Selected land use parameters, environmental conditions, drainage and precipitation data, along with storm water pollution factors provided input data for functional relationships to enable assessment of pollution from storm water runoff.

Recommendations were made for a plan of action for preventing and controlling storm water pollution from urban areas.

ACCESSION NO:

KEY WORDS:
Storm Water Pollution
Urban Runoff
Land Use Indicators

BIBLIOGRAPHIC: Avco Economic Systems Corporation,
Storm Water Pollution from Urban Land Activity,
FWQA Publication No. 11034FKL07/70, 1970.

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